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ABSTRACT

This study on problem solving used a sample of 92 people, broken down as follows: 56 first year chemistry students, 18 Tertiary Orientation Project (T.O.P.) students, 7 H.S.C. students, 8 second year chemistry students, 2 staff members, and 1 technician. Subjects were each given four elementary organic chemistry problems. Each session consisted of up to one hour for solving the problems, and approximately two hours for completing a knowledge test, an IQ test, and the California Personality Inventory (C.P.I.) test. Subjects were asked to think aloud into a cassette recorder while they were reading problems and during the knowledge test. Three cassettes were analyzed, leaving 89 for further study. The aim was to see if: (1) there were generalizable problem-solving strategies similar to the ones described by Bruner in concept attainment; (2) these can be identified by use of Mandell's PSBTS methodology; and (3) there are correlations between IQ, psychological makeup, and student problem-solving behavior. Results provided strong evidence of the use of identifiable and generalizable problem-solving strategies, but there was little correlation between subjects' IQ's, C.P.I. profiles, and problem-solving strategies. (MP)

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Caulfield Institute of Technology

Student Strategies
in
Problem Solving

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Report to the New Initiatives Committee
Project N 862

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November 1981

E 037 071

AN INVESTIGATION
INTO
THE PROBLEM SOLVING STRATEGIES
OF
SOME H.S.C. AND 1ST YEAR STUDENTS

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Lead me
from untruth to truth
from death to immortality
from darkness to light.

Brihadaranyaka Upanishada

We wish to thank the New Initiative Committee for a grant (N 862) to enable us to undertake this project. The investigators are also grateful to the Committee for allowing a twelve month extension of time. The original grant application contained a request for a full time research assistant with a background in educational research. As the investigators were unsuccessful in getting such assistance, the entire processing of data generated has had to be done by them during non-teaching weeks. This is why completion of the project took approximately two years.

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January, 1982

AN INVESTIGATION INTO
THE PROBLEM SOLVING STRATEGIES
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SOME H.S.C. AND 1ST YEAR CHEMISTRY STUDENTS

1. BACKGROUND OF THE PRESENT WORK

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1. BACKGROUND OF THE PRESENT WORK

One of the investigators in this project (Dr J.B. Bapat), spent one year in the Chemical Education Sector of the University of East Anglia between 1974-75 and undertook research into problem solving processes.[1]

The conclusions of this research project were as follows:

1.1 In spite of the completely non-homogenous nature of the subject group, 95% of the subjects solved the problems by strategies that fitted Gagnéian hierarchies.

1.2 The subjects whose solutions did not fit the hierarchy patterns, attempted problems in a 'Heuristic' fashion.

1.3 Protocol Analysis appears to be a very satisfactory and useful method of investigating problem solving strategies and the factors that may lead to these strategies.

1.4 More than 90% of the subjects used an analytical approach as against an 'intuitive approach'.

1.5 In spite of the possession of requisite basic knowledge as determined by a knowledge test, most subjects in the study were unable to solve the problems. The result suggested the presence of one or more factors between knowledge possession and problem solution.

The above project used M.Sc. and Ph.D. students and the teaching staff of the University of East Anglia as the sample. However, because of the nature of sample, some of the conclusions reached were not unexpected. For instance, most scientists are trained to think logically and hence would be expected to follow a logical and hence hierarchical thought process in their problem-solving activity. The experiment at East Anglia raised many interesting and fundamental questions and showed many pitfalls in this type of research. It was therefore decided to repeat the above experiment with the following modifications:

A) A sample of H.S.C. or 1st year students should be used, thereby avoiding the necessity of making the problems too complex.

B) It was decided that a correlation analysis of students IQ and personality test scores with success in problem-solving would be worthwhile attempting.

C) It was thought that a serious attempt at studying student problem-solving strategies should be made and if identified as such, the different strategies should be correlated with success in problem-solving.

The current project represents this strategy in studying problem-solving behaviour of C.I.T. TAFE and 1st year students.

2. THE PROCESS OF PROBLEM SOLVING

2.1 What is Problem-Solving?

Problem-solving is the most complex form of human activity. There is however, considerable confusion as to the meaning of the term. Thus, concept formation, recall of complex rules, creativity, deductive and inductive reasoning and many aspects of the thinking process, have been at one time or another, called Problem-solving.[2] Educational psychologists however agree that problem-solving and creativity stand at the highest level of behavioural hierarchy since they both involve extremely complex cognitive processes.[3]

Problem-solving is a unique interaction between a person and his surroundings. The problem solver is faced with a gap between what he knows and the solution he is required to produce. In order to close this gap, he must combine and transform his original knowledge.* Educational psychologists like Gagné, Green and Ausubel maintain that true problem solving can only be said to have occurred when a person learns a generalizable rule for himself for the first time.[4,5,6,7] Gagné has in fact called problem-solving hierarchically the highest form of human activity. According to him, problem-solving comprises a change in human performance which leads one to infer a change in human capability. The most important characteristic of this activity is the lack of its specificity. The problem solver may not realise that learning has occurred unless he performs a 'transfer experiment.[8] This newly acquired capability thus consists of applying a newly acquired rule to specific situations. The rule learned can be very complex and in most cases the problem solver cannot state it. This is where, according to Gagné, problem solving differs from simple recall of previously learned concepts or principles.

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* P-s is thus an activity whereby the best value is determined for an unknown, subject to specific conditions. 4

Gagné has given a very attractive definition of problem solving which is as follows:

> "Problem-solving is an inferred change in human behaviour which results in the acquisition of a generalizable rule which is novel to the individual, which cannot be established by direct recall and which can manifest itself in applicability to the solution of a class of problems."

The work described in this investigation is based on this definition of problem solving and this is reflected in the design of problems 3 and 4. However, the investigators are well aware that in examination situations such as that encountered by the first year students at C.I.T. Students may not necessarily face 'true problems' most of the time. Problems 1 and 2 in this investigation were therefore deliberately designed as "recall" and "application of recall" respectively, i.e. in Gagnéian sense, they are not true problems.

2.2 Measurement of Mental Ability

Conceptions of mental ability stem mainly from two distinct approaches: psychometric and clinical,[9,10,11]. The clinical approach substitutes for the impersonal paper and pencil format of group tests, a situation in which the subject is observed by a skilled observer while solving problems. It supplements the objective score with the impressions of the observer. Statistical analyses and comparison with other individuals carry much less weight in this approach; subjective interpretation of the observer is considered very much more important. The clinical approach is thus identified with the study of emotional and personality characteristics as against measurement of mental ability. Because it is concerned mainly with individual testing and wholistic interpretations, the clinical psychologists have developed neither techniques nor concepts for measurement of Problem-solving ability. This is in sharp contrast to the elaborate correlation methodology and factor theory of the psychometric approach.

In summary, then, the clinical approach lacks the conceptual and methodological tools whereas the psychometric approach with its emphasis on scores and traits cannot look effectively at individual differences in process. An understanding and evaluation of human thought processes will have to take into account the similarities and differences amongst people. Then only a serious attempt can be made to improve educational procedures as this requires knowledge of how thought processes affect learning.

We believe that it is obviously advantageous to arrive at a mean by combining both approaches so as to produce a more complete picture of the problem solving individual. We have therefore resorted to a combination of measurement of several parameters as well as a detailed analysis of student protocols.

2.3 Models of Problem Solving

Theoretical models of the problem solving process have helped the conduct of the research in this field greatly. There are three main types of models that have been responsible for the advances in this area:

2.3.1 Creative problem solving models.
2.3.2 Approaches that stress human ability.
2.3.3 Information processing models.

2.3.1 Creative Problem Solving Models

These models grew out of research into creativity and divergent thinking spearheaded by Guildford and Torrance. Osborne, the father of the brainstorming technique, developed the following model:

Osborne's Creative Problem Solving Model: This is built around ten activities as follows:-

(i) consider all aspects of the problem
(ii) select a sub-problem to be solved
(iii) identify data that may be used
(iv) choose sources of data
(v) think of all possible leads to a solution
(vi) select most promising leads
(vii) identify ways to test a solution
(viii) pick the best test
(ix) think of all possible contingencies and solutions
(x) select the final best answer.

Torrance and Myers' Model: Torrance and Myers[12] have described similar steps in creative problem solving. These are:-

(i) setting up conditions
(ii) sensing problems of challenges
(iii) recognizing the real problem
(iv) producing alternative solutions
(v) evaluating ideas
(vi) preparing to implement ideas.

Other creative problem solving models have used similar steps,[13,14,15]. Feldhusen and Guthrie have reviewed most of the models and proposed two new ones.[10]

2.3.2 Approaches That Stress Human Ability

Guildford's Structure of Intellect Model: Global ability and component factors are the two main concepts of human intelligence and both of these are traits that differentiate people. Hunt[16] has suggested that intelligence can profitably be conceptualised in terms of processes, citing the examples of concepts used in developmental studies by Piaget and in computer models.

Modern factor theories provide a beginning to the problem of bridging the gap between concepts of trait and of process. Guildford's 'Structure of Intellect' model defines factors in terms of the intellectual operations to be performed, the contents upon which they are performed and the product that ensues. Each ability is thus defined in terms of a specific problem. The primary intellectual abilities may therefore be conceived as ways of functioning within individuals as well as ways in which individuals differ from one another.

Analysis of factors as ways of functioning suggest questions at two levels of analysis.

(a) What is the nature of the functions involved? Do individuals differ in the processes by means of which they solve factorized problems, and the number of problems they can solve?

(b) How do these ways of functioning operate and interact in the solution of complex problems?[4]

Guildford *et al.*[17, 18] hypothesised that problem solving consists of five steps: Preparation, analysis, production, verification and reapplication. They postulated that problem-solving ability was multidimensional and from factor analysis of the results of 219 students, several factors pertaining to each stage of the theoretical model were isolated. Five kinds of psychological operations were differentiated. Cognition, memory, convergent production, divergent production and evaluation. The model was content divided into three types: figural (shape, size, etc.) symbolic (letters, numerals, etc.) and semantic (units, classes, transformations, etc.). The authors came up with ten factors that they thought were very important in problem solving. A later study[15] by Guildford and Hoepfner[16] hypothesized six factors and a possible separate general problem solving factor. These are:

1. Ability to think rapidly of several attributes of an object
2. Ability to classify objects or ideas
3. Ability to find different relations between attributes of an object or situation
4. Ability to think of alternative outcomes of a given situation
5. Ability to list attributes of a goal
6. Ability to educe logically sufficient anticidents to a situation
7. A general problem solving factor.

Tests indicated support for 2, 3, 5 and 6th factors but no support for 1, 4 and 7th factors. According to the authors, then, there is no evidence of a unitary problem solving ability.

Feldhusen *et al.*[19] have proposed a twelve factor model.

Information Processing Models: The work of Newell and Simon[20] paved the way to the current trend towards viewing mental activities as information processing systems. Studies in computer simulation of thought processes have led researchers in this area to view cognitive phenomena, learning and perception as, "Human Information Processing". The performance of persons in performing complex tasks is seen to be under the control of processes or functions that operate on symbolically coded information stored in memory. As a person performs a task, the details of the process; i.e. the level, organization and sequencing, is thought to change. These details that change with the process are then the mechanisms by which people take in, organize, transform, process, store and retrieve information about their environment. From this viewpoint, investigations of problem solving, memory, creativity, etc., are studies of how persons process and transform information, either received from outside or already stored in memory.

Its emphasis on process has given information processing psychology two characteristic methodological features: detailed protocol analysis for the collection of data, and analysis and simulation model building as a means of studying theoretical processes. Information processing models have several characteristic postulates; the following are relevant in defining variation in process.

(a) Immediate memory is limited to a small number of units.

(b) Long range memory has fewer limitations, its availability depends upon its organization for retrieval.

(c) Problem-solving consists of searching a very large array of possible solutions to discover a 'real' solution.

(d) The search is selective rather than exhaustive.

(e) The search is accomplished by utilizing elementary information processes, e.g. comparing, transforming, finding differences and arranging into processes and sub-processes.

(f) The selections are made on the basis of heuristics or decision criteria designed to discover an acceptable solution rather than a best or optimal one.

(g) The selection heuristics are organized hierarchically, i.e. the result of a test determines the subset of tests from which the next selection is made.

Models having these characteristics have been developed for a variety of problem types and it has been suggested that variants of a basic model might serve as models for individuals. By developing a model whose operation is subject to variation according to input parameters, one may develop a theory of individual differences in problem solving process.

Newell and Simon's Model: Newell and Simon propose that human problem solving takes place in a problem space constructed when a problem occurs. This space consists of a set of elements (u), a set of operators (Q), an initial state of knowledge (uo), a problem, a desired state (G) and the total knowledge available. Basic components of the model include a long term memory, a short term memory, serial processing limited by individual rate of processing, sensory systems to acquire information about the environment and external memory aids available.

Newell and Simon's model throws light on a number of basic processes involved in human problem solving and integrates a number of concepts involved in cognitive processes.

Scandura's Model:[4, 21] This model is based on a conception of rules of hierarchical orders and control mechanisms. Memory is represented in terms of structural networks. Scandura claims that the model is useful to study the processes underlying problem solving.

Gagne's Model:[6] This is also an 'IPS' model which stresses that, rules of how to solve a class of problems are learned or derived from problem solutions. Students develop general approaches to classes of problems and these are called, "cognitive strategies". These strategies direct the goal seeking process and are responsible for coding for long term storage and retrieval. Gagné asserts that all aspects of problem-solving behaviour are teachable. A similar model has been described by Miller *et al.*[22]. The basic unit of behaviour in their model is TOTE, Test-operate-test-exist.

A model incorporating deductive reasoning in the Piagetian sense and alogrithmic processing in the information processing sense has been described by Pitt[10]. The model incorporates the Piagetian model of formal operational thought and Polya's problem solving heuristic model[23].

2.3 Strategies in Problem-Solving

2.3.1 Definition

Strategy, a word originally used for military manoeuvres, has been used rather loosely in psychology. Ausubel[3] describes a strategy as a set of verbal rules which guide selection and manipulation of background information whereas Goss[24] equates 'abstract sets, attitudes, hypotheses and strategies. Johnson[2] defines strategy as a method for collecting and retaining relevant information, for formulating and testing hypotheses, for representing and transforming the data and for detecting the errors; in short, a method of finding the method of solution. Butcher[25] states that the idea of strategy is less general than the idea of a set or attitude and not as specific as the testing of a particular hypothesis. According to him, initial 'set' is important when the method of solving a problem is still obscure, whereas the formation and testing of a hypothesis is the terminal stage in solving a problem. In between these stages it is necessary to consider alternative plans of action, to foresee how unsatisfactory hypotheses can be effectively eliminated and to put into action the best available procedure. This intermediate stage, according to Butcher, is the strategy.

In view of the above discussion, the best general definition seems to us to be, "Starting from knowledge possession, strategy is the art of reaching the solution".

2.3.2 Work in the area of problem solving strategies

There appear to be essentially two types of work on strategies in the literature. The first type is directed towards improving problem solving ability in general and the theoretical and psychological aspects of the problem solving process are not taken into consideration. Examples of this kind involve general rules like 'stop and think'[26]. There are several books, written primarily for management trainees which represent work of this type[27, 28, 29]

The second type involves research into the psychology of problem solving process and attempts to appreciate the reasoning behind strategy constructs.

2.3.2.1 Behavioural variables and strategy constructs

Harootunian and Tate[30] studied the effects of several variables on problem solving ability. The variables studied were problem recognition, word fluency, ideational fluency, closure, judgement, test intelligence and reading ability. Multiple regression analysis of the test results with 636 8th grade students indicated that most important of the seven variables were reading, test intelligence, judgement and problem recognition.

The effect of 'set' on problem-solving has been studied in detail and the concept has been reviewed by Kellogg[31]. A mental set can

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be defined as cognitive operations that predispose the learner to perceive and approach a situation in a given way. The solution of problems can be greatly influenced by the mental set which the learner brings to the problem or which is induced by the method of instruction. This can lead to certain cognitive strategies dominating attempts at solution even when a number of approaches of equal probability are possible for a solution. Thus, if the chosen strategy is appropriate for solving the problem, performance may improve but if the strategy is not relevant, performance is retarded.[32,33,34]

The most common general labels for strategies seem to be logical (analytical) and intuitive (heuristic, mnemonic). Goldman[34] studied the effects of a logical versus mnemonic learning strategy in undergraduate psychology students. He found that those using a logical strategy received significantly higher grades on many academic criteria like course grades, test grades and laboratory grades. However, it is important to note that the two strategy groups did not differ significantly on six ability measures (general reasoning, vocabulary, syllogistic reasoning, indirection, number facility and associative memory). The results suggested that it may be possible to seek "most-efficient" strategies for given tasks and perhaps, most efficient strategies for individual ability profiles.

Thorsland and Novak[35] were able to identify consistent individual differences in problem solvers and to divide them into Analytic (A) and Intuitive (I) approaches. The authors found that individuals were reasonably stable in their A or I approach from problem to problem.

The authors claimed that people with high 'I' ability (having the global superordinate concepts in a discipline and having the ability to reconstruct lower level concepts) achieve more and learn more efficiently than those people with high A (those that generate subordinate concepts but lack the overall subsuming concepts).

Lindahl[36] correlated matriculation marks and the strategy adopted in problem solving/concept learning for 164 students. The students were college psychology students who had attended different courses at college. The students were divided into those having matriculation science and others. Lindahl concluded from the results that working perceptually was preferred to working conceptually, because the former is normally less trying to humans. The author suggests that humans are highly sensitive to recurrences of environmental contingencies. These recurrences are registered immediately and are essential for maintaining a perceptually loaded strategy. If the sensation fails to appear despite repeated scannings, it may then trigger a conceptually loaded strategy. The problem solving is thus more knowledge-bound the more conceptually oriented the information collecting is, and more stimulus bound the more perceptually oriented the information collecting.

Using the well known Hanoi Tower puzzle as an example, Simon[37] showed that even with simple problems, numerous solution strategies were possible and different subjects may learn by different strategies. He described four different solution strategies and showed that they had different degrees of transferability, placed different burdens on short term memory and on perception and required different learning processes for their acquisition.

Dufresne-Tassé and others[38] observed subjects solving Maier's hatrack problem[39] and compared the strategies used by successful versus unsuccessful problem solvers. The authors found that the successful problem solvers displayed the following characteristics: (1) they constructed fewer unrelated basic assemblages than those who failed; (2) their exploration of one single idea seemed to take longer and they were more capable than those who failed in following one single idea from a basic assemblage through to a more elaborate one; (3) they changed their behaviour more in the second half of the time span which they devoted to the solution of the problem; (4) at that stage, they tried harder to find the solution than those who failed and they modified their solutions more; (5) they arrived more often at the acceptable solution without reaslising it than those who failed.

Some of the above findings are also echoed by Christensen-Szalanski[40]. Using a cost-benefit analysis, the author observed that as the benefit of making a correct decision increased,problem solvers took more time to reach a solution. He suggests that more valuable problems make potentially more accurate, complex and costly stragegies worth using. People thus actually consider the potential pay-offs and costs of engaging in various acts, however roughly and imperfectly they may do it and that they use these considerations to guide their behaviour. Christensen Szalanski's findings could have an important bearing on the selection of strategies by problem solvers.

Wood and others[41] have shown that although subjects may employ representational strategies when they first encounter a class of problems, they abandon such strategies when they gain experience with the problems. The authors have shown that increasing experience with problems is paralleled by decreasing ability to answer unexpected questions.

Marshall[42] studied selection of strategies in problem-solving by administering a 'strategy assessment test' immediately after the subjects completed their problem solving. The test assessed the extent to which subjects employed various cognitive strategies at different times. The results of the strategy scores led to six clusters denoting higher order approaches to the task. These were flexible idea production, systematic and flexible approach, active analytic observation, analytic focus on patterns and details, passive scanning and reliance on initial ideas". Strategy preferences, deployment and strategy effectiveness varied as a function of subject's abilities and as a function of differences in treatment group instructions and subject's behaviour in the initial part of problem-solving task.

2.3.3 Teaching Problem-Solving Strategies

Attempts at teaching problem-solving strategies have had some degree of success. In order to identify strategies used in concept learning, Tagatz[43] used a novel plan. This plan consisted of programming students with the strategy, having them attain a concept and finally examining whether or not the strategy had been followed. This allowed the author to appraise the relative efficacies of the strategies being compared. Two strategies were compared: A conservative strategy of a verbally presented alogrithm and a commonality strategy articulating a method of solution whereby the characteristics common to a set of conceptual examplars. Very few of the students used the conservative strategy which required greater use of formal logic than the commonality plan.

Means[44] studied college students solving timer-tape problems. She was able to separate them into intuitive and logical problem solvers and found the former to perform poorly. The poor performance was however identified as due to the use of an incorrect solution strategy rather than cognitive inability. Once the correct strategy was explained by intuitive responders, they seemed to understand it to realize that their own responses had been incorrect. The intuitive responders were quite confident about their responses until the correct solution strategy was explained to them. The author suggested further examining problems that elicited an intuitive response.

In an attempt to modify problem solving performance, Young[45] investigated three procedures: (a) unaided experience, (b) experience plus exposure to strategies described only as a procedural change and (c) experience plus exposure to strategies described explicitely as solution strategies. She found that procedure (a) was the least effective technique while procedure (c) was the most effective method.

2.3.4 - Rationale for the Present Research

A perusal of the above work on strategies clearly shows that the classification of strategies is, at best, vague. Thus the various labels used for describing strategies are "logical, intuitive, mnemonic, inductive and deductive". We find it difficult to adequately describe strategies by using one or more of the above labels.

For one of us (J.B.B.), the main interest in undertaking this research was to seek a more exacting classification of strategies used in problem solving; more precisely, a classification that linked the psychological make up of a person to strategy constructs. In this connection, the work of Bruner *et al.*, dealing with selection strategies in concept attainment is most important. In their classic work, "A Study of Thinking", Bruner, Goodnow and Austin[46] have described four strategies a person may use in concept attainment. These are:
a) simultaneous-scanning strategy; b) successive scanning strategy;
c) conservative focussing strategy and d) focus gambling strategy.
A brief description of these strategies is as follows:

Simultaneous Scanning Strategy:

This consists of a person using each instance encountered as an occasion for deducing which hypotheses are tenable and which have been eliminated. Bruner *et al.* say that this is a highly exacting strategy because the subject must deal with many independent hypotheses and carry these in memory. Moreover, the deductive process is exacting. To follow the strategy successfully, the subject's choice of next instances to test will be determined by the objective of eliminating as many hypothetical concepts as possible. While it may be possible for the person to plan the best next step, the task of guaranteeing maximum informativeness of a next choice would, in practice, be too difficult to accomplish. Thus, in terms of assimilation and retention of information contained in instances encountered, simultaneous scanning is too difficult a strategy.

Successive Scanning Strategy

This strategy consists of testing a single hypothesis at a time. This is done until the correct answer is achieved. The typical successive scanner then limits his choices to those instances that provide a direct test of his hypothesis.

Bruner *et al.* quite rightly point out that this technique gives no assurance that the instances chosen will provide the maximum possible information. One is likely to choose logically redundant instances which do not lead to the solution of the problem. The strategy does not regulate risk either. Successive scanners quite often play the 'guessing game' in choosing the order of hypotheses to be tested.

The gain, by successive scanning is relief of cognitive strain. Limited interference is required and the principal strain on memory is to keep track of what hypotheses have already been tested and found wanting.

Conservative Focussing Strategy:

In this strategy, the subject finds a positive instance and uses that as a focus, then makes a sequence of choice each of which alters but one attribute value of the first focus. A test is then made to see if the change yields a positive or negative instance. Those attribute values of the focus, which when changed, still yield positive instances are NOT part of the solution and so on.

This strategy guarantees that each instance produces information. Redundancy can thus be completely avoided. There is no risk element in this strategy since every choice is safe and logically guarantees the presence of information in the instance chosen for testing. The only notable disadvantage is the possibly difficult task of search in a complex problem situation.

Focus Gambling Strategy:

The main feature of this strategy is that the subject uses a positive instance as a focus and then changes more than one attribute value at a time. Focus gambling could lead to the solution in fewer trials than in using conservative focussing but the strategy may also require many more attempts than conservative focussing. Thus, if one were to take such a risk, the solution may be very fast, very slow or in between.

As explained earlier, Burner and co-workers described these strategies in the context of concept attainment. However, we believe that it would be reasonable to invoke these (or at least very similar ones) for the process of problem solving. In the current project an attempt was made to find out if such strategies could be identified in student problem solving from a detailed analysis of student protocols and their script books. This was done and the results obtained are described in the next chapter. It was, however, felt that such an attempt, at best, would be very subjective, since there are no known quantifiable measures that differentiate between these strategies.

It was therefore thought that if some quantifiable labels could be assigned to strategies, their differentiation may be achieved more easily. Models of problem solving essentially look at the thought processes involved and hence in effect, strategies. It was therefore decided to investigate strategies by using a suitable model of problem solving.

In this context, a recent paper (1980) by Mandell[47] appeared most interesting. After studying several models of problem solving, Mandell chose a model consisting of the following four phases: (i) initial attack, (ii) follow up phase, (iii) incubation phase, and (iv) solution phase. Using these four phases, he then developed a Problem Solving Behaviour Tally Sheet (P.S.B.T.S.) as follows:

Definitions of Terms Used on the P.S.B.T.S.

A. *Initial Attack Phase*

(This phase can be identified as identifying the problem. In the language of Wicklegren (1974): the subject is cataloging the "givens, operations, goals,"). Ref. 29.

A-1:	Relational Statements	Verbalization of recognition of type of problem, type of attack, or solution needed similarity to another problem: the "aha" phenomenon of Bruner (1963). Ref. 46.
A-2:	Negational Statements:	Verbalization of processes, attacks, or solutions deemed not appropriate: identification of nonessential information in problem: the "exclusion" phenomenon.

B. *Follow-Up Phase*

(This phase can be described as the hypothesis formation phase: the "creative phase" of Rogers (1962).) Ref. 48.

B-1:	Random Trial and Error:	Verbalization of nonorganized patterns of attack.
B-2:	Systematic Trial and Error:	Verbalization of organized patterns of attack.
B-3:	Classifactory Trial and Error:	Verbalization of ordering, prioritizing, patterns of attack.
B-4:	Inferential Statements:	Verbalization of specific inference from data provided.

C. *Incubation Phase*

(This phase can be identified as testing hypotheses: the "checking stage" of Rogers (1962).)

C-1:	Inductive Statements:	Verbalization of generalizations from specifics.
C-2:	Deductive Statements:	Verbalization of specifics from generalizations.
C-3:	Tentative Manipulations:	Verbal or physical processing of data.

D. *Solution Phase*

(This phase can be described as stating the conclusions.)

D-1:	Relational Statements:	Verbalization of the solution using positive statements.
D-2:	Negational Statements:	Verbalization of the solution using negative statements.

Mandell had each student speak into a cassette recorder during problem solving and these protocols were then transcribed word for word.

For each student, the percent distribution of categorized statements according to phases (A - D) and type of behaviour within each phase (A_1 or A_2, B_1 or B_2 or B_3 or B_4, etc.) were calculated. These results provided a description of the relative distribution of the types of behaviour that the students used in attempting to solve the problem, i.e. the problem solving strategy employed by each student for each problem.

Mandell gave the students six problems in mathematics and found that different strategies were effective for different problems. He also found that there were significant differences in strategies between the superior problem solvers and the non-superior problem solvers. However, the study did not attempt to investigate if the strategies were generalizable for a class of problems.

To us, Mandell's methodology appeared very attractive. As far as we know, his was the first attempt to place the study of strategies on a semi-quantitative foundation. The only limitation of such a study would appear to be that the types of behaviours within the four phases are not really generalizable strategies. We therefore decided to investigate whether Mandell's P.S.B.T.S. methodology could be used to identify Bruner type generalizable strategies in student problem solving using protocol analysis as a tool. This has been the major thinking behind the present study. The methodology used is described in the next section.

3. DESIGN AND CONDUCT OF THE EXPERIMENT

3.1 Sample

The sample consisted of 92 people of whom,

56 were first year chemistry students (CHE III),
18 were Tertiary Orientation Project (T.O.P.) students,
7 were H.S.C. students,
8 were second year chemistry students, and
3 were staff (2) and technicians (1).

3.2 Conduct of the Test

C.I.T. language laboratory was extremely useful for the conduct of this project. The subjects were given four elementary organic chemistry problems each. The session consisted of up to 60 minutes for solving the problems and the remaining time (approximately two hours) for completing a knowledge test, an IQ test and the California Personality Inventory (C.P.I.) test.

As soon as they started reading each problem (and also during the knowledge test) the subjects were asked to think aloud into a cassette recorder. A C-90 cassette was used for each student. The need for recording their thoughts was explained to them beforehand both orally and in writing. A few weeks before the students undertook the test, one of us (J.B.B.) personally taught them the background knowledge necessary to be able to solve the problems. At the end of the problem solving session, the students completed a "Background Knowledge Test". This test was designed to ascertain if the subject had acquired the pre-requisite knowledge. It was however, felt that the knowledge test alone was not adequate to ascertain the subjects' knowledge and a combination of this test, protocols and the script book was used to decide a pass or failure in the knowledge test.

At the conclusion of the session, the following materials were collected:

(a) 92* cassettes : these were transcribed word for word,

(b) 92 script books : these were marked in conjunction with the transcribed protocols.

Attached to the script book was also a questionnaire that allowed the subjects to express their opinions on the problems. A sample test paper along with the instructions and the questionnaire is attached in Appendix A.

3.3 Processing of the Protocols

Each protocol was processed according to Mandell's P.S.B.T.S. scheme. An example is given below:-

Student Name: A. White Year Group : CHE 228 (2nd year chemistry)

Problem No. 4.

(Repeats the question) ... work out the mechanism first. Ethanol is CH_3CH_2OH (A_1). Reacts with methanol CH_3OH. CH_3O^{θ}... $CH_3^{\oplus}$... (B_3). It must lose OCH_3 ... (B_4). One more mole of methanol. Can't see where it is going to attack, lose H_2O (C_3). Go out to there (C_3)(C_2). Create a double bond. Add another molecule of methanol (B_2).

$\therefore$ 1) Total number of strategy statements in the order they appear =

A_1, B_3, B_4, C_3, C_3, C_2, B_2.

---

* Three cassettes were unrecorded and hence only 89 were chosen for further study.

This information was then recorded for each student as follows:

Student No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Comments
85	A.White	CHE228	4	✓	$A, B_3, B_4,$ C_3, C_3, C_2 B_2	✓	Logical start but wrong. Tries OMe, Me as leaving groups. Then comes to losing water. Hence correct answer.

The results of such processing for all students are given in Appendix B (pages B_1 to B_{39}).

4. RESULTS AND DISCUSSION

4.1 Statistical Treatment of the Results

The processing of results of the data in Appendix B was done mainly by a statistical approach. In this approach, factor analysis was used to examine the relationship between the various variables which are given in Table 1. Table 1(a) lists the intercorrelations between these variables.

In order to reduce the dimensionality of a set of variables, by taking advantage of their intercorrelations, factor analysis was utilised since both meaningful and fundamental dimensions of multi-variate domains can thus be identified.[51]

To isolate a small number of factors which would account for much of the variation in the large number of Chemistry test, personality and cognitive strategy measures a principal axis form of factor analysis was used. Communalities were estimated by the use of squared multiple correlations. The resulting factors were orthogonal.

In order to increase the likelihood that the resulting factors would be meaningful a normalized Varimax rotation was used. This resulted in a closer approximation to simple structure[52] and, by producing few high loading variables on each factor with other variables loading near zero, it permitted more meaningful interpretation at the basis of the high loading.

The factor solution deemed to best reflect the true essence of the relationship between the variables was based on principles established by Kaiser and Harman who suggest that factors which account for true or common variance among the variables in a matrix are those whose eigenvalues

TABLE 1

VARIABLES USED IN FACTOR ANALYSIS

1.	Chemistry test : total recall (Problem 1)	CHEMISTRY TEST RESULTS
2.	Chemistry test : application of recall (Problem 2)	
3.	Chemistry test : number of problems solved (problems 3 and 4)	
4.	I.Q. (OTIS Higher Test Form A)	PERSONAL MEASURES
5.	Age	
6.	Sex	
7.	CPI : Dominance	PERSONALITY MEASURES (CALIFORNIA PERSONALITY INVENTORY)
8.	CPI : Capacity for status	
9.	CPI : Sociability	
10.	CPI : Social presence	
11.	CPI : Self acceptance	
12.	CPI : Sense of well-being	
13.	CPI : Responsibility	
14.	CPI : Socialization	
15.	CPI : Self control	
16.	CPI : Tolerance	
17.	CPI : Good impression	
18.	CPI : Communality	
19.	CPI : Achievement via conformance	
20.	CPI : Achievement via independence	
21.	CPI : Intellectual efficiency	
22.	CPI : Psychological mindedness	
23.	CPI : Flexibility	
24.	CPI : Femininity	
25.	Initial Attack : Relational statements	COGNITIVE STRATEGY MEASURES (MANDELL'S PSBTS SCHEME)
26.	Initial Attack : Negational statements	
27.	Follow-up phase : Random trial and error	
28.	Follow-up phase : Systematic trial and error	
29.	Follow-up phase : Classificatory trial and error	
30.	Follow-up phase : Inferential statements	
31.	Incubation phase : Inductive statements	
32.	Incubation phase : Deductive statements	
33.	Incubation phase : Tentative manipulations	
34.	Solution phase : Relational statements	
35.	Total number of different cognitive strategies	

exceed unity[53]. It was also important to account for as high a percentage of variance as possible, given these other parameters, and to minimise the number of variables that do not load significantly on any factor.

In order for a significant loading to be established it was determined that a variable must load 0.33, accounting for 10% of the variance on a factor.

RESULTS

Interpretation of the Factor Solution

The principal axis analysis of thirty-five variables consisting of three from success in testing recall, success in application of recall and knowledge of Chemistry principles; (success in solving the problems); three measures of individual capacities (age, intelligence and sex); eighteen personality measures as indicated by the California Psychological Inventory[54]; and elevan measures of cognitive strategies[47]; thirty-five variables in all, resulted in nine factors with eigenvalues greater than unity. This nine factor solution was appropriate for interpretation since only eight of the variables loaded significantly on two factors and two loaded significantly on three factors. Thus the nine factor solution was regarded as essentially clean; none of the thirty-five variables failed to load significantly on at least one factor. The nine factor solution accounted for 73.0% of the variance. The correlation matrix and the factor matrix of the nine factor rotated solution are presented in Tables 2 and 3.

Factor 1 - Mature and Responsible Socialisation

This first factor is defined by eight significant loadings, all in the positive direction. The variables are all in the groups designated

Class 2 (measures of socialisation, maturity, responsibility and intrapersonal structuring of values) and Class 3-(measures of achievement potential and intellectual efficiency) of the California Psychological Inventory[54].

The only variable from which three classes of variables not included as a descriptor of Factor 1 is communality which is an important definer of factor 5. Of the variables which load heavily on factor 1, self-control, the ability to assess the degree and adequacy of self-regulation and freedom from impulsivity and self-centredness is most important with a loading of + 0.89. Other variables contributing to the definition of this factor are tolerance (+ 0.74), good impression (+ 0.72), responsibility (+ 0.65), intellectual efficiency (+ 0.63), achievement via conformance (+ 0.62), achievement via independence (+ 0.62), and socialisation (+ 0.59). This factor which accounted for 19.8% of the variance was interpreted as mature and responsible socialisation. It was interesting to note that none of the loadings from the Chemistry tests, none of the cognitive strategy measures and none of the personal measures loaded significantly on this factor.

Factor 2 - Sophisticated Cognitive Strategies

This factor is defined by nine significant loadings all of which are cognitive structure measures. Essentially the cognitive structure measures all load on this factor but those of greatest import in its definition are classificatory trial and error which loads + 0.78, tentatively manipulation (+ .78) and the total number of different strategies (+ .78). Others which load significantly are in order negational statement (+ .68), relational statement (+ .67), inferential statement (+ .65), systematic trial and error (+ .61), relational statement in the solution phase (+ .56), and tentative manipulation (+ .55).

Of the four different phases comprising cognitive problem-solving strategies namely:

1. initial attack A
2. follow-up phase B
3. motivation phase C
4. solution phase D,

emphasis in this factor is on the intermediate phase and components of those which characterise sophisticated and complicated processing. Thus the factor which accounts for 14.0% of the variance has been named Sophisticated Cognitive Strategies. The stark independence of this second factor is again noteworthy. Only two of the cognitive structure variables failed to load significantly on this factor and no other variables from any of the other three domains approaches significance.

Factor 3 - Sociable Self-Confidence

Factor 3 is defined by five significant positive loadings all members of Class 1, measures of poise, ascendancy, self assurance, and interpersonal adequacy from the C.P.I. The most significant variable defining this factor is sociability (the capacity to identify persons of outgoing sociable participatary temperament), which loads + 0.87. Other significantly loading variables are self acceptance (+ 0.78), social pressure (+ 0.78), dominance (+ 0.75), and capacity for status (+ 0.63).

The only variable in the Class 1 set which failed to load significantly on this factor was sense of well-being which comprises the definition of Factor 5. Interestingly variables from the C.P.I. Class 3 set also load significantly but all have larger significant loadings on other factors and can thus be ignored in the definition of this factor. Tentatively interpretated Sociable Self Confidence, this third factor accounts for 11.1% of the variance. Again the clarity of the interpretation is remarkable in that variables from only one specified domain define this factor.

Factor 4 - Chemistry Test

This factor is defined by only three significant loadings all of which derive from the Chemistry tests. The most important loading is application of recall (+ .83) with knowledge test (+ .76), and total recall (+ .73). A fourth Chemistry test result designated 'problems' was omitted from analysis as a consequence of two few scores. Another variable which loads significantly on factor 4 is one of the cognitive strategy measures, deductive statement in the inculcation phase (+ .34). Thus Factor 4 which accounts for 6.7% of the variance is tentatively interpreted as a Chemistry Test factor.

To this point the results are strikingly clear. The four factors interpreted to date which collectively account for 51.6% of the variance demonstrate no overlap between the domains of this investigation.

Factor 5 - Confident Intellect

Factor 5 is defined by three variables. The highest loading variable is communality, from Class 2 of the C.P.I., which loads + .80; sense of well being, from Class 1 of the C.P.I. which loads + .61 and I.Q. based on the ACER Intermediate A Test which loads 0.57. Accounting for 5.2% of the variance this factor is tentatively interpreted as Confident Intellect. Little additional insight is gained from an examination of this factor although it does embrace two of the domains of the study.

Factor 6 - Flexibility

Factor 6 is defined by three significant loadings two of which (capacity for status and achievement via independence) have higher loadings on alternative factors. Essentially the factor is interpreted as flexibility, one of the Class 4 measures of the C.P.I. It accounts for only

4.8% of the variance and adds little to an investigation of the relationships between variables in the different domains.

Factor 7 - Simple Incubation

Factor 7 which accounts for 4.1% of the variance is defined by the first 2 variation phase cognitive strategy measures : individual statement which loads -.61 and deductive statement which loads + .54. Age also loads significantly on this factor (+ .57). This factor is tentatively interpreted as Simple Incubation.

Factor 8 - Psychological Inclination

Factor 8 is defined by two of the C.P.I. measures - feminity (+ .47) and psychological mindedness (+ .44). Both are from Class 4 of the C.P.I. measures. This factor accounts for 3.8% of the variance and is tentatively interpreted as a Psychological Inclination factor.

Factor 9 - Sex

Factor 9 contributes 3.4% of the variance and has only one significant loading, sex (+ 0.51).

The results based on this interpretation of a factor analysis of variables from four different domains embracing personality and personal measures as well as Chemistry test results and associated cognitive strategy measures provides no evidence for relationships across domains. Based on the total sample of 89 subjects, variables cluster only with other variables within a specified domain.

4.2 Explanation of Factor Patterns Associated with Success and Non-success Groups of Students

The criterion variable was chosen from among the initial measures of competence in chemistry. The variable, Knowledge Test, was chosen as the best single indicator of problem solving competence and because it provided a greater range of scores than possible alternative variables and approximated a normal distribution (Kurtosis - 0.41 and Skewnessu - .36). A median split was achieved using this variable; students who scored 6 or less were designated 'dull' (N = 42) while students scoring 7 or above were designated 'bright' (N = 47). Factor patterns for each group on the total set of variables were compared with each other, i.e. the 'bright' group was compared with the 'dull' group and with the previously described pattern established with the total sample (N = 89).

Interpretation of the factor pattern for the 'Dull' group (N = 42)

The five factor solution which accounted for 60.0% of the variance was chosen for interpretation since it provided the most psychologically meaningful relationships and the cleanest solution. The correlation matrix and the factor matrix of the five factor rotated solution are presented in Tables 4 and 5.

Factor 1 - Personal Adequacy:

The first factor is defined by twelve variables, eleven of which are in the positive direction and one, femininity, in the negative direction. Essentially though the factor is not bipolar since the loading of femininity (- 0.38) is barely significant. The factor is defined by measures from the California Psychological Inventory predominantly measures of poise, ascendancy and self-assurance. One cognitive strategy measure, inductive statement in the incubation phase, loads on this factor and ? provides the only link, albeit small, between personality measures and a measure of cognitive strategies. The factor accounts for 20.0% of the variance and is tentatively interpreted as Personal Adequacy.

Factor 2 - Sophisticated Cognitive Strategies:

This factor is defined by eight significant loadings all of which are cognitive structure measures. Only two inductive and deductive statements in the incubation phase, are omitted from the set defining this factor. 14.9% of the variance is accounted for and the factor tentatively interpreted as Sophisticated Cognitive Strategies.

Factor 3 - Mature Responsibility:

Five significant loadings, essentially measures of socialisation, maturity and responsibility define this factor which accounts for 10.4% of the variance and is interpreted as Mature Responsibility.

Factor 4 - Social Maturity:

Five significant positively loading variables define this factor which accounts for 7.8% of the variance. Some integration of domain is achieved in this factor with three personality measures all providing indications of social maturity are found together with intelligence and chemistry problem solving ability. The factor is however relatively small and inconsequential being the fourth to emerge in so-called 'dull' groups. The factor has tentatively been interpreted as Social Maturity but provides only very tenuous links between the domain of this study.

Factor 5 - Chemistry Test Factor:

Factor five accounts for 6.9% of the variance and is defined by chemistry test results and deductive statements in the incubation phase. There is thus slight evidence of an association between a cognitive strategy and chemistry test taking ability. The factor is tentatively interpreted as a Chemistry Test factor.

Interpretation of the Factor Pattern for the 'Bright' Group (N = 47)

Again the five factor solution was selected for interpretation; it was both cleanest, most meaningful and permitted the most expeditious comparisons. The correlation matrix and the factor matrix of the five factor rotated solution for 'bright' subjects are presented in Tables 5 and 6.

Factor 1 - Maturity Factor

This factor being defined by nine significantly loading variables all from the C.P.I. accounted for 21.1% of the variance and was tentatively interpreted as a Maturity Factor. No insight into relationships between different domains in this study was possible since the loadings were from one domain only.

Factor 2 - Sophisticated Cognitive Strategies

This factor was defined by nine of the eleven cognitive strategy measures. The inductive and deductive statements again did not load with the others. The factor accounted for 14.8% of the variance and was tentatively interpreted as Sophisticated Cognitive Strategies.

Factor 3 - Problem Solving Ability

This was defined by six positively loading variables, the most important of which were three indicators of success with the Chemistry Test: problems, knowledge test and application of recall. The two cognitive strategy measures, deductive and inductive statements in the incubation phase, loaded respectively 0.65 and 0.50 thus enabling an interpretation which spanned domains. This is probably the most important factor in the total set since it reveals an association between success at chemistry problems and high frequency usage of deductive and inductive statements among students designated bright.

Factor 4 - Personal Assurance

Accounting for 6.2% of the variance Factor 4 was defined by five C.P.I. variables describing personal assurance and relatively low loading of age. Little interpretable meaning could be ascribed to this factor.

Factor 5 - Personal Potential

Accounted for only 5.4% of the variance and was defined by three C.P.I. variables which assessed personal potential, the name tentatively given to this factor.

Comparison of the 'Dull' group and the 'Bright' group with the total sample

As can be seen from the description of the factor pattern for the dull and the bright group substantial comparability exists between the factor solutions. In the bright group there is some evidence linking success on chemistry problems with a capacity for utilizing inductive and deductive statements but for the remainder of the factors interpreted in both these groups and in the total sample the domain of chemistry test results, personality, cognitive strategies and personal measures remain separate.

4.3 Discussion

When the 35 variables were subjected to factor analysis using the total sample of 89 subjects it was apparent that virtually no links existed between variables from more than one domain. The 35 variables were classified into 4 domains (see Table 6) and the factors which emerged demonstrated relationships between variables within, rather than across domains. That is, there were no links between different measures of chemistry test performance and personal measures, personality measures and cognitive strategy measures. Variables clustered only with other variables from a specified domain.

TABLE 6

LIST OF VARIABLES FROM EACH DOMAIN IN THE STUDY

CHEMISTRY TEST RESULTS

1. Chemistry test: total recall (Problem 1)
2. Chemistry test: application of recall (Problem 2)
3. Chemistry test: number of problems solved (Problems 3 and 4)

PERSONAL MEASURES

4. I.Q. (OTIS Higher Test Form A)
5. Age
6. Sex

PERSONALITY MEASURES

7. CPI: Dominance
8. CPI: Capacity for status
9. CPI: Sociability
10. CPI: Social presence
11. CPI: Self acceptance
12. CPI: Sense of well-being
13. CPI: Responsibility
14. CPI: Socialization
15. CPI: Self control
16. CPI: Tolerance
17. CPI: Good impression
18. CPI: Communality
19. CPI: Achievement via conformance
20. CPI: Achievement via independence
21. CPI: Intellectual efficiency
22. CPI: Psychological mindedness
23. CPI: Flexibility
24. CPI: Femininity

COGNITIVE STRATEGY MEASURES

25. Initial Attack: Relational statements
26. Initial Attack: Negational statements
27. Follow-up phase: Random trial and error
28. Follow-up phase: Systematic trial and error
29. Follow-up phase: Classificatory trial and error
30. Follow-up phase: Inferential statements
31. Incubation phase: Inductive statements
32. Incubation phase: Deductive statements
33. Incubation phase: Tentative manipulations
34. Solution phase: Relational statements
35. Total number of different cognitive strategies.

There existed a possibility that differential chemistry ability contributed strongly to this result in the sense that capable chemistry students may be able to be described in terms of specified personality measures and may have used selected cognitive strategies in arriving at solutions to the problems. On the other hand, less capable chemistry students may have been much more diffuse in both personality and choice of cognitive strategies. Pooling both these groups, as was done in the initial part of the data analysis, may have prevented the emergence of clear and interpretable relationships.

With this in mind, using a median split on the criterion variable Knowledge Test, two groups were isolated : one designated "dull", the other "bright". When additional factor analyses were computed with these selected groups, there emerged some evidence of an association between a cognitive strategy measure and chemistry test taking ability. In the "dull" group this association was between success in chemistry problem solving and personality measures indicating social maturity (see Factor 4). A more powerful indication was found in Factor 3 - Problem Solving Ability, with the "bright" group. Here students who had performed well on the chemistry tests displayed a strong tendency to use deductive and inductive argument in the incubation phase. Links between personality and use of these cognitive strategies for "bright" and for "dull" students were not able to be established.

Table 1(a)

Intercorrelations of Chemistry test results, personal measures, personality measures and cognitive strategy measures. (N = 89)

Variable

1 Chemistry test: total recall
2 Chemistry test: application of recall
3 Chemistry test: no. of problems solved
4 IQ
5 Age
6 Sex
7 CPI: Dominance
8 CPI: Capacity for status
9 CPI: Sociability
10 CPI: Social presence
11 CPI: Self acceptance
12 CPI: Sense of well-being
13 CPI: Responsibility
14 CPI: Socialization
15 CPI: Self-control
16 CPI: Tolerance
17 CPI: Good impression
18 CPI: Communality
19 CPI: Achievement via conformance
20 CPI: Achievement via independence
21 CPI: Intellectual efficiency
22 CPI: Psychological mindedness
23 CPI: Flexibility
24 CPI: Femininity
25 Initial attack: Relational statements
26 " " : Negational "
27 Follow-up phase: Random trial and error
28 " " : Systematic trial and error
29 " " : Classificatory trial and error
30 " " : Inferential statements
31 Incubation phase: Inductive statements
32 " " : Deductive statements
33 " " : Tentative manipulations
34 Solution phase: Relational statements
35 Total number of different cognitive strategies

* Decimal points omitted.

For 100 df, two tailed, r = .195 (p=.05) and r = .254 (p=.01).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
-																																		
64	-																																	
62	59	-																																
13	24	33	-																															
12	-00	12	03	-																														
-18	-22	16	-07	-03	-																													
-01	12	07	06	08	08	-																												
-01	18	10	08	16	-22	58	-																											
-01	22	17	20	08	-14	71	60	-																										
-02	31	11	32	06	-13	46	56	74	-																									
13	41	23	25	20	-10	57	48	69	30	-																								
00	08	-06	31	26	-02	23	29	32	03	30	-																							
-02	-23	-14	03	17	-05	22	21	09	13	03	38	-																						
15	09	12	-02	05	-02	18	07	09	-27	13	45	46	-																					
-09	-19	-17	11	14	-06	-02	06	16	08	-27	45	55	44	-																				
-12	-04	-05	07	10	-15	29	47	28	-09	08	52	53	33	59	-																			
-08	-15	09	-25	14	-18	23	29	03	23	-09	23	40	26	70	54	-																		
03	07	10	45	18	-02	11	06	24	35	23	67	27	47	15	19	10	-																	
01	-03	09	17	18	-02	47	26	40	11	35	53	51	50	46	48	30	38	-																
-04	00	-02	24	20	-12	23	49	24	33	11	53	44	10	50	69	41	26	49	-															
07	07	-01	[illegible]	21	-03	40	43	46	2	33	71	48	40	45	65	34	47	[illegible]	59	-														
-05	11	08	03	10	-26	41	34	39	06	29	32	25	02	31	46	33	-06	39	48	44	-													
02	11	04	19	12	11	22	39	14	02	06	23	14	-07	12	23	08	03	04	47	28	22	-												
09	04	20	-20	16	01	11	14	14	-17	02	-19	04	11	-06	-20	-03	06	12	-32	-20	-24	03	-											
-01	-04	00	-27	-11	-05	-03	-03	07	-02	-17	-28	-04	-10	-07	-08	04	24	14	-14	-12	05	-06	-02	-										
03	06	02	03	-19	-18	10	02	04	07	-02	-01	03	-13	-04	05	-01	00	14	03	08	-01	26	10	41	-									
-11	-02	-12	-17	-25	-07	13	15	05	00	07	-15	07	01	05	12	14	12	09	11	13	06	26	-04	37	43	-								
10	02	02	05	-07	-05	03	02	00	-03	00	-24	-04	-20	-22	-15	-17	09	16	19	04	01	02	-02	56	37	21	-							
-03	01	06	-02	-18	-08	-02	05	05	-12	-03	-27	-07	-17	-03	11	16	25	22	04	-03	-06	16	03	47	61	53	37	-						
00	-08	04	-09	-25	-27	-10	-05	13	35	-12	-26	-05	-10	00	-08	11	20	22	20	-19	-05	10	04	44	52	26	33	53	-					
10	20	31	19	40	10	16	34	31	27	35	06	-02	-09	-19	17	-04	09	09	06	14	04	09	-00	-05	-02	09	12	06	-14	-				
20	33	41	26	17	05	14	14	25	05	27	26	-12	-13	-08	02	-04	19	20	06	15	22	02	04	04	04	-20	15	03	-14	41	-			
00	04	04	-10	-26	16	02	00	01	01	05	-37	-13	-16	-16	-08	-02	25	25	-18	-05	-17	04	-05	42	54	60	45	72	48	12	-04	-		
02	13	04	-05	-02	-17	10	03	03	33	01	-16	-13	05	-02	11	03	13	13	-09	-12	01	-01	09	43	22	25	37	44	53	-02	-06	37	-	
12	27	22	12	-14	-07	21	09	26	33	33	06	-14	03	-07	07	-03	01	08	-03	10	12	08	-10	48	50	37	51	61	35	24	34	55	46	-

Table 2

Rotated (orthogonal) factor loadings of Chemistry test results, personal measures, personality measures and cognitive strategy measures. (N = 89)

	Variable	I	II	III	IV	V	VI	VII	VIII	IX	h^2
1	Chemistry test: total recall	-01	00	-04	73	05	01	05	09	08	70
2	Chemistry test: application of recall	-13	03	23	83	09	07	-02	08	10	75
3	Chemistry test: no. of problems solved	-06	04	09	75	02	-04	23	13		70
4	IQ	-09	-05	11	15	57	18	11	20	13	56
5	Age	18	-21	06	01	06	03	57	24	12	64
6	Sex	-08	-11	10	-19	02	15	00	02	51	51
7	CPI: Dominance	24	01	74	00	-07	01	03	01	04	81
8	CPI: Capacity for status	24	-01	63	02	09	43	18	06	13	78
9	CPI: Sociability	08	01	86	05	13	03	09	07	01	79
10	CPI: Social presence	-05	-05	77	05	26	09	02	23	15	87
11	CPI: Self acceptance	-04	02	78	21	19	00	13	07	03	83
12	CPI: Sense of well-being	54	-20	21	01	60	04	09	15	05	89
13	CPI: Responsibility	65	-05	07	16	13	06	00	17	01	65
14	CPI: Socialization	58	-07	10	19	30	-31	-28	40	08	79
15	CPI: Self-control	89	-05	26	07	-02	00	04	06	08	93
16	CPI: Tolerance	73	-00	20	-04	05	28	03	17	01	79
17	CPI: Good impression	71	04	00	-05	-32	08	03	01	12	78
18	CPI: Communality	22	-14	11	03	80	-03	06	13	04	78
19	CPI: Achievement via conformance	62	-14	37	02	28	18	08	06	08	77
20	CPI: Achievement via independence	61	-08	14	-02	16	50	15	30	07	83
21	CPI: Intellectual efficiency	63	01	37	02	37	14	08	13	09	85
22	CPI: Psychological mindedness	40	01	41	01	10	03	05	44	31	76
23	CPI: Flexibility	15	11	12	01	10	54	14	07	10	64
24	CPI: Femininity	-07	00	11	11	-09	-08	11	47	05	57
25	Initial attack: Relational statements	-02	67	05	-06	-19	21	04	05	11	66
26	" " : Negational "	00	68	-10	03	15	25	-06	00	04	75
27	Follow-up phase: Random trial and error	13	55	12	07	-15	28	19	05	21	70
28	" " : Systematic trial and error	-17	60	03	-03	03	12	18	07	06	73
29	" " : Classificatory trial and error	02	80	-06	03	-15	26	01	00	07	86
30	" " : Inferential statements	-05	65	13	-03	-10	07	18	12	33	71
31	Incubation phase: Inductive statements	-03	06	27	17	04	18	60	05	13	70
32	" " : Deductive statements	-02	06	14	34	18	-15	54	26	00	75
33	" " : Tentative manipulations	-12	78	03	03	-18	14	-08	03	42	84
34	Solution phase: Relational statements	-04	56	-00	05	-04	-10	-04	11	26	68
35	Total number of different cognitive strategies	01	78	24	23	13	-15	11	20	08	91
	Percentage of variance accounted for	19.8	14.0	11.1	6.7	5.2	4.8	4.1	3.8	3.4	(73.0)

* Decimal points omitted

Variable

1 Chemistry test: total recall
2 Chemistry test: application of recall
3 Chemistry test: no. of problems solved
4 IQ
5 Age
6 Sex
7 CPI: Dominance
8 CPI: Capacity for status
9 CPI: Sociability
10 CPI: Social presence
11 CPI: Self acceptance
12 CPI: Sense of well-being
13 CPI: Responsibility
14 CPI: Socialization
15 CPI: Self-control
16 CPI: Tolerance
17 CPI: Good impression
18 CPI: Communality
19 CPI: Achievement via conformance
20 CPI: Achievement via independence
21 CPI: Intellectual efficiency
22 CPI: Psychological mindedness
23 CPI: Flexibility
24 CPI: Femininity
25 Initial attack: Relational statements
26 " " : Negational "
27 Follow-up phase: Random trial and error
28 " " : Systematic trial and error
29 " " : Classificatory trial and error
30 " " : Inferential statements
31 Incubation phase: Inductive statements
32 " " : Deductive statements
33 " " : Tentative manipulations
34 Solution phase: Relational statements
35 Total number of different cognitive strategies

* Decimal points omitted.

For 100 df, two tailed, $r = .195$ ($p=.05$) and $r = .254$ ($p=.01$).

Table 3

Intercorrelations of Chemistry test results, personal measures, personality measures and cognitive strategy measures for students designated "bright". (N = 47)

Variable

1 Chemistry test: total recall
2 Chemistry test: application of recall
3 Chemistry test: no. of problems solved
4 IQ
5 Age
6 Sex
7 CPI: Dominance
8 CPI: Capacity for status
9 CPI: Sociability
10 CPI: Social presence
11 CPI: Self acceptance
12 CPI: Sense of well-being
13 CPI: Responsibility
14 CPI: Socialization
15 CPI: Self-control
16 CPI: Tolerance
17 CPI: Good impression
18 CPI: Communality
19 CPI: Achievement via conformance
20 CPI: Achievement via independence
21 CPI: Intellectual efficiency
22 CPI: Psychological mindedness
23 CPI: Flexibility
24 CPI: Femininity
25 Initial-attack: Relational statements
26 " " : Negational "
27 Follow-up phase: Random trial and error
28 " " : Systematic trial and error
29 " " : Classificatory trial and error
30 " " : Inferential statements
31 Incubation phase: Inductive statements
32 " " : Deductive statements
33 " " : Tentative manipulations
34 Solution phase: Relational statements
35 Total number of different cognitive strategies

* Decimal points omitted.

For 100 df, two tailed, r = .195 (p=.05) and r = .254 (p=.01).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
-																																		
61	-																																	
65	45	-																																
34	24	12	-																															
19	-02	31	-03	-																														
-19	-25	11	-05	-10	-																													
08	12	-18	-05	-02	-14	-																												
-11	15	-01	00	-16	-16	71	-																											
-07	08	04	13	-22	-10	81	72	-																										
-[illegible]	24	-06	41	-21	-04	56	61	77	-																									
04	37	11	22	-06	-08	59	51	62	76	-																								
00	19	27	31	26	04	24	22	22	34	33	-																							
-13	-29	26	11	17	-03	22	10	11	13	07	23	-																						
17	17	06	-16	07	-04	17	-14	08	08	23	46	30	-																					
-18	-10	-18	-16	26	-04	-08	-06	-18	-10	-19	37	39	39	-																				
-38	-21	04	00	03	-08	31	44	33	25	05	35	45	13	55	-																			
-25	-05	07	-46	16	-24	24	24	05	00	-05	04	17	14	63	42	-																		
09	18	-24	39	08	[illegible]	09	00	00	29	29	65	08	43	02	-04	-30	-																	
-09	-02	25	13	17	-01	56	31	40	52	51	5[illegible]	46	46	44	45	33	23	-																
-21	-05	15	24	17	-11	35	57	35	43	21	45	46	-03	42	64	28	19	45	-															
-16	06	20	10	08	06	54	50	48	53	41	61	27	31	43	59	24	31	56	56	-														
-35	11	+10	01	12	-37	47	47	45	55	35	[illegible]	27	00	40	51	41	-07	45	57	51	-													
11	28	12	31	16	-09	30	41	18	26	20	33	19	02	06	21	01	05	06	44	39	22	-												
10	-05	26	-36	07	07	-20	-32	-32	-41	-18	-37	-20	-02	-11	-30	-02	-30	-33	-43	-36	-29	02	-											
-36	-08	15	-43	-14	-14	02	-06	10	-02	-05	-14	-07	03	14	00	15	-10	12	-10	-01	20	-05	21	-										
-16	03	-02	-06	-17	-17	01	-01	11	05	10	-18	-16	-29	-25	-08	-11	-27	-13	-06	-04	03	35	27	50	-									
-29	03	-01	-19	-40	07	35	39	29	35	39	09	-07	04	05	10	20	-03	27	36	49	26	36	02	33	47	-								
06	01	08	-08	01	-09	03	-04	-04	01	10	-43	-15	-31	-32	-31	-23	-19	-17	-31	-01	-02	-03	29	27	25	13	-							
-30	-05	27	-13	-18	-05	-04	03	-02	-04	-03	-11	-17	-25	06	15	04	-30	-20	10	03	08	24	23	56	73	42	18	-						
-20	-04	08	-10	-26	-41	-14	-10	-04	-08	02	31	-24	-20	-10	-19	-03	-31	-14	-13	-20	07	15	19	44	65	31	23	51	-					
-02	-01	-36	05	02	-06	41	49	29	25	39	-01	10	-18	-27	13	04	-14	15	19	13	05	25	06	-11	03	19	35	03	-19	-				
13	19	37	18	00	-22	19	13	21	16	16	09	-19	-40	-23	-17	01	07	14	-12	-04	08	15	05	34	25	06	30	11	09	35	-			
-28	-04	15	-09	-30	35	23	16	23	22	31	-17	-23	-25	-24	-09	-17	-26	00	-14	20	-02	20	14	33	66	56	42	57	31	23	17	-		
-24	13	-07	-10	-03	-39	-29	-21	-17	02	12	13	-11	26	14	-32	-10	19	00	-09	-11	03	-05	21	25	18	14	12	13	45	-17	00	13	-	
-01	24	35	10	-23	-39	27	19	29	30	40	16	-06	10	-05	-09	-11	-02	28	-07	21	22	19	05	45	58	44	52	58	46	28	52	58	39	-

Table 4

Rotated (orthogonal) factor loadings of Chemistry test results, personal measures, personality measures and cognitive strategy measures for students designated "bright". (N = 47)

	Variable	I	II	III	IV	V	h^2
1	Chemistry test: total recall	-07	-29	-21	15	71	65
2	Chemistry test: application of recall	14	01	-14	32	57	61
3	Chemistry test: no. of problems solved	10	09	-02	40	24	37
4	IQ	24	-21	-26	43	-02	46
5	Age	-12	-23	27	07	23	40
6	Sex	-07	-12	-18	03	-47	41
7	CPI: Dominance	81	01	14	-03	17	81
8	CPI: Capacity for status	86	-01	10	-12	02	72
9	CPI: Sociability	82	05	00	06	00	81
10	CPI: Social presence	79	05	-02	32	-07	77
11	CPI: Self acceptance	67	13	-10	37	17	76
12	CPI: Sense of well-being	26	-14	38	71	-04	65
13	CPI: Responsibility	20	-21	43	07	-17	46
14	CPI: Socialization	-07	-10	39	51	11	46
15	CPI: Self-control	-16	03	91	13	-07	63
16	CPI: Tolerance	41	-07	64	-08	-30	64
17	CPI: Good impression	12	03	72	-35	21	63
18	CPI: Communality	09	-24	-01	75	-01	65
19	CPI: Achievement via conformance	49	02	48	33	02	56
20	CPI: Achievement via independence	52	-09	51	13	-16	64
21	CPI: Intellectual efficiency	59	06	44	32	-19	61
22	CPI: Psychological mindedness	51	15	49	01	06	57
23	CPI: Flexibility	37	17	09	15	12	44
24	CPI: Femininity	-38	28	-14	-21	21	43
25	Initial attack: Relational statements	06	73	16	-07	-01	65
26	" " : Negational "	07	78	-18	13	04	73
27	Follow-up phase: Random trial and error	41	55	10	03	-11	56
28	" " : Systematic trial and error	06	38	38	-11	16	52
29	" " : Classificatory trial and error	02	75	04	-14	-10	73
30	" " : Inferential statements	-13	68	-07	-13	07	65
31	Incubation phase: Inductive statements	50	03	-17	-12	16	49
32	" " : Deductive statements	23	26	-22	02	35	52
33	" " : Tentative manipulations	29	65	-33	-09	-25	64
34	Solution phase: Relational statements	29	44	03	39	08	45
35	Total number of different cognitive strategies	28	80	-12	32	16	65
	Percentage of variance accounted for	20.0	14.9	10.4	7.8	6.9	(60.0)

* Decimal points omitted

Table 5

Intercorrelations of Chemistry test rests, personal measures, personality measures and cognitive strategy measures for students designated "dull". (N = 42)

	Variable
1	Chemistry test: total recall
2	Chemistry test: application of recall
3	Chemistry test: no. of problems solved
4	IQ
5	Age
6	Sex
7	CPI: Dominance
8	CPI: Capacity for status
9	CPI: Sociability
10	CPI: Social presence
11	CPI: Self acceptance
12	CPI: Sense of well-being
13	CPI: Responsibility
14	CPI: Socialization
15	CPI: Self-control
16	CPI: Tolerance
17	CPI: Good impression
18	CPI: Communality
19	CPI: Achievement via conformance
20	CPI: Achievement via independence
21	CPI: Intellectual efficiency
22	CPI: Psychological mindedness
23	CPI: Flexibility
24	CPI: Femininity
25	Initial attack: Relational statements
26	" " : Negational "
27	Follow-up phase: Random trial and error
28	" " : Systematic trial and error
29	" " : Classificatory trial and error
30	" " : Inferential statements
31	Incubation phase: Inductive statements
32	" " : Deductive statements
33	" " : Tentative manipulations
34	Solution phase: Relational statements
35	Total number of different cognitive strategies

* Decimal points omitted.

For 100 df, two tailed, r = .195 (p=.05) and r = .254 (p=.01).

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
-																																	
54	-																																
18	24	-																															
02	25	10	-																														
-17	00	-09	05	-																													
14	03	20	22	01	-																												
17	15	05	47	-28	44	-																											
34	28	26	41	-17	60	47	-																										
40	39	21	33	-23	33	50	72	-																									
40	25	26	41	-11	57	44	75	60	-																								
04	-03	33	25	-09	22	35	41	37	30	-																							
-20	-29	-04	17	-06	23	31	08	-06	00	49	-																						
-08	00	11	03	02	19	-01	09	-08	00	46	63	-																					
-28	-42	-07	06	-07	03	15	-14	-37	-32	50	66	52	-																				
03	-09	12	15	-21	27	48	23	21	09	66	60	53	64	-																			
-21	-36	-04	23	-14	23	35	02	-20	-10	38	59	42	77	66	-																		
-05	17	51	26	-04	13	11	10	20	18	58	41	52	25	35	06	-																	
-13	-04	20	20	07	38	19	12	08	20	56	57	53	43	51	30	49	-																
03	-03	22	22	-11	10	41	13	06	01	60	43	24	58	74	54	32	52	-															
03	-06	34	32	-10	29	36	44	31	27	79	62	49	47	68	43	58	63	62	-														
21	-02	08	06	-12	31	29	33	38	22	44	22	07	26	44	23	-04	33	38	41	-													
03	00	08	08	-15	12	38	13	13	-03	15	09	-16	16	27	13	02	03	50	20	21	-												
03	17	-08	23	-03	-01	00	-01	-02	13	-07	24	22	-03	-16	-03	09	03	-24	-11	-19	-06	-											
-05	-06	-22	-11	-01	-06	-12	-17	-18	-23	-33	-03	-17	15	-14	-01	-29	-25	-17	-17	-03	-06	-11	-										
08	-18	14	-22	-18	-26	-04	-22	-14	-14	12	19	03	11	19	10	21	-15	12	18	-07	18	-04	40	-									
-01	-13	-15	-17	-18	-04	-03	-11	-31	-11	-28	14	00	06	17	11	-16	-21	-02	-04	-10	19	-07	39	42	-								
00	-02	10	-12	00	03	08	08	03	-08	-11	04	-11	-16	-02	-11	-02	-01	-09	07	04	07	-24	74	50	27	-							
-03	-11	06	-19	-08	00	06	10	-26	-05	-35	00	-13	-09	05	24	-23	-20	-02	-09	-18	15	-11	45	54	61	51	-						
-21	-23	-10	-25	-11	-05	08	-23	-36	-25	-22	09	-03	05	-02	22	-14	-30	-15	-30	-18	10	-08	46	38	25	42	54	-					
28	50	30	62	-10	-05	23	31	25	31	12	-07	-04	-16	16	-09	21	05	20	13	04	01	01	-03	-08	06	-04	05	-13	-				
34	53	33	26	11	13	15	26	21	31	38	-07	03	-02	03	-07	25	23	14	23	37	-01	00	-08	-13	-32	04	-15	-34	42	-			
00	-10	-14	-26	04	-16	-15	-22	-34	-14	-46	-06	-11	-13	-12	09	-27	-43	-22	-22	-31	-03	-18	47	47	65	47	80	58	02	-20	-		
12	09	00	-62	-15	08	14	08	03	-07	-33	-02	-13	-11	04	13	-32	-22	-09	-13	-01	02	01	52	26	32	57	65	60	06	-12	52	-	
11	-04	09	-07	-06	15	-05	20	13	22	01	-21	-10	-08	18	08	-03	-16	00	-02	02	03	-22	44	43	39	52	63	24	16	16	51	52	-

Table 6

Rotated (orthogonal) factor loadings of Chemistry test results, personal measures, personality measures and cognitive strategy measures for students designated "dull". (N = 42)

	Variable	I	II	III	IV	V	h^2
1	Chemistry test: total recall	03	16	27	-09	26	48
2	Chemistry test: application of recall	-19	04	59	19	19	61
3	Chemistry test: no. of problems solved	-06	18	86	04	20	67
4	IQ	30	04	41	15	-08	51
5	Age	17	-16	20	42	06	62
6	Sex	-01	-12	-05	-12	-25	28
7	CPI: Dominance	17	-01	-06	68	09	60
8	CPI: Capacity for status	14	01	05	57	48	50
9	CPI: Sociability	13	-05	27	84	08	75
10	CPI: Social presence	05	-14	45	63	16	72
11	CPI: Self acceptance	04	-05	31	79	-06	75
12	CPI: Sense of well-being	75	-25	26	19	28	79
13	CPI: Responsibility	73	04	-31	11	19	66
14	CPI: Socialization	70	-06	-08	01	-07	63
15	CPI: Self-control	66	-10	-38	-22	43	7[illegible]
16	CPI: Tolerance	65	06	-02	17	58	74
17	CPI: Good impression	50	12	-40	05	49	77
18	CPI: Communality	80	-10	33	10	-29	68
19	CPI: Achievement via conformance	66	-31	-02	20	11	63
20	CPI: Achievement via independence	54	-09	09	-01	64	74
21	CPI: Intellectual efficiency	76	-03	17	25	31	79
22	CPI: Psychological mindedness	16	-14	15	22	53	44
23	CPI: Flexibility	06	08	-02	10	40	50
24	CPI: Femininity	06	-13	-09	12	-27	24
25	Initial attack: Relational statements	-18	64	-01	-14	04	74
26	" " : Negational "	26	65	07	-26	06	54
27	Follow-up phase: Random trial and error	-01	60	-24	-04	06	65
28	" " : Systematic trial and error	-01	70	16	-03	03	74
29	" " : Classificatory trial and error	-08	88	-13	02	07	80
30	" " : Inferential statements	-06	61	-25	-14	05	60
31	Incubation phase: Inductive statements	06	05	50	22	04	62
32	" " : Deductive statements	13	-14	65	10	08	67
33	" " : Tentative manipulations	-16	82	-12	-15	-08	80
34	Solution phase: Relational statements	-19	69	-01	13	15	65
35	Total number of different cognitive strategies	-02	67	16	17	05	6[illegible]
	Percentage of variance accounted for	21.1	14.8	12.8	6.2	5.4	(60.2)

* Decimal points omitted

4.4) An Analysis of Strategy Profiles

In order to compare and contrast the strategy profiles of students for each problem, the percentage of each of the cognitive strategy measures (Mandell's PSBTS measures p. 20) was calculated. This information is presented in tabular form in Appendix C . (p.C_1 to C_{27}.) An examination of these tables shows some very interesting patterns listed below:

4.4.1) If the subjects had the necessary knowledge (as shown by a pass in the knowledge test) a high score in either C_1 (inductive statement) or C_2 (deductive statement) or both, correlated very higly with success in problem solving. Thus, almost without exception, the successful problem solvers had consistently high scores in C_1 and/or C_2.

The correlation of C_1 and/or C_2 with success in problem solving has also been shown in the factor analytic approach discussed in (4.1).

4.4.2) Stategies such as successive scanning, simultaneous scanning and focus gambling could be clearly identified in many protocol transcripts.

Examples:

1) Subject: No. 78
   Problem: 3.2
   Strategy: Focus gambling

2) Subject: No. 89
   Problems: 3.1 and 3.2
   Strategy: Focus gambling

3) Subject: No. 85
   Problems: 3.1., 3.2., 3.3.,
   Strategy: Successive scanning

4) Subject: No. 22
   All problems
   Strategy: Successive scanning

It is with a strong belief that such strategies do exist in problem solving that this work was started. It was heartening to see that this indeed was the case.

4.4.3) If the trial and error approach, (simultaneous or successive seannings) was unsuccessful, subjects resorted to gambling. However, in the majority of the cases, this gambling was NOT focus gambling. It consisted of random wild guesses which has no bearing on the information provided and which invariably led to failure. We prefer to call this behavious "NON-FOCUS GAMBLING". Subjects utilizing this approach did no worry about the cost benefit analysis of the situation and they had a very high percentage of C_3 statements (tentative manipulations) in their protocols.

Examples: Subject No. 33

4.4.4) Many subjects tackled all four problems in more or less similar manner. This finding has a very important implication that there may be a basis for generalizable stratigies in problem solving. Some examples:

Subject No's: 39, 78, 65, 57, 5, 33, 89, 22, 88, 92.

4.4.5) Several subjects, in spite of possessing the basic knowledge required to solve the problems, resorted to a 'Non-focus gambling strategy in all the problems and were unsuccessful as a result.

This finding, first of all, strengthens the previous one that many subjects tend to use identical strategies for the problems they attempt.

Secondly, it shows that some strategies can be couterproductive for a class of problems, an observation made previously by Simon [37] and Mandell [47].

4.4.6) Many subjects failed to use all the information given. Without assimilating all the information provided, they resorted to "Focus gambling". The first positive instance led to a dead end. The subjects at this stage were lost and could not revert to correct courses.

4.4.7) Many examples were seen where the phenomenon of 'set' acted against the subjects[31]. This was seen several times in the inability of the students to write the structure of oxalic acid. Examples: Subject No's: 44, 89, 18, 72.

They could not imagine two carboxylic acid groups tied together without any other groups being present. Some in fact remarked that, "This was unreal and impossible".

4.4.8) Scientific problems such as these lend themselves to a logical approach. This can take the form of conservative focussing, successive scanning or simultanious scanning. It was found that most successful problem solvers chose a very logical strategy.

5. Epilogue

As stated earlier, the aim of this study was to seek answers to the following questions:

a) Are there generalizable problem solving strategies similar to the ones describes by Bruner in concept attainment?

b) Can these be identified by use of Mandell's PSBTS methodology?

c) Are there correlations between the IQ, the psychological make up (as studies by California Personality Inventory) and the problem solving behaviour of students?

It would be clear from section (4.2) that at least as far as our sample and problems are concerned, the answers to questions (a) and (b) are in the affirmative. We have seen strong evidence of the use of identifiable and generalizable problem solving strategies by the subjects in our study.

It appears from section (4.1) that as far as these problems and the present sample are concerned, there is little correlation between the subjects' IQ's, their C.P.I. profiles and the strategies they adopt. The only correlation observed is between the use of inductive and deductive statements and success in problems for the bright students. The lack of correlation between IQ, CPI profiles and success in problem solving is to us, very surprising and we are at this stage, unable to advance any clear cut reasons for this. One can rationalize that IQ may not have a relationship with the type of strategy a subject chooses to adopt and hence one sees no correlation. However, we would have expected a correlation between CPI profiles and the strategy adopted (C_1, C_2, and C_3 scores with CPI profiles) Failure to observe this is to us an important avenue for further investigation.

5.1) Implications of the Investigation for Teaching:

The Analysis of strategy profiles described in section (4.4) has several important implications for teaching. These can be summarized as follows:

a) Since we have shown that inductive and deductive thinking play a major role in successful problem solving we believe it is essential for the students to be taught these formal logical processes. It is our observation that tertiary students in Science and Engineering hardly receive any training in the area of problem solving, let alone in inductive and deductive thinking. Although of utmost importance to them in passing examinations and their future job requirements, problem solving training is a sadly neglected area in tertiary education. We believe that it is possible to develop lecture material to train students in inductive and deductive thinking and in problems solving in general. This should be mandatory in all the teaching courses at a tertiary instution, irrespective of the nature of the course.

b) Students need also be given training in the use of problem solving strategies. This study has shown that certain strategies can be couterproductive and it is important that the students realise the cost-benefit aspect of the strategy they adopt.

c) To encounter the possible negative effect of "set", a technique such as brainstorming should be routinely used with students.

5.2) Future Directions of Research

This study comes out with a very important finding that generalizable strategies may exist for a class of problems. Because of the profound implications of this finding, we believe that this work should be repeated for all classes of problems and hopefully confirmed. We ourselves will be interested in duplicating this in a humanities area.

A possible reason for the lack of correlations between IQ, CPI profiles and problem solving strategies could be the possible inadequacy or unsuitabiltiy of the PSBTS methodology for the problems at hand.

Several times during our attempts to assign PSBTS labels to student statements, we came across cases where none of the PSBTS labels were appropriate. Some inadequacies of PSBTS are as follows:

5.2.1) Many subjects work through the problem in a forward fashion. Others start with a possible answer and work backwards. Strategically, there are important differences between these behaviours but PSBTS cannot distinguish between the two.

5.2.2) Items B, (random trial and error) B_2 (systematic trial and error) and B_3 (classificatory trial and error) are to us somewhat vague descriptors of what possibly are the major strategy behaviours. These descriptors, to us, should be considerably modified or changed to adequately describe this important aspect of strategy.

We plan to develop a much more detailed model which will hopefully rectify the shortcomings of PSBTS model. This may then show the correlations we are looking for. Theoretical work in the area of problem solving is extremely challenging, interesting and in most cases, unrewarding. We do believe we have obtained some reward for this work in the results obtained and we wish to pursue this further with added vigour.

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APPENDIX A

THE STUDENT TEST PAPER

C.I.T.

TO THE STUDENTS.

This exercise is aimed at gaining some knowledge of the 'problem solving process'. In other words, we want to find out why many students cannot solve problems!

To understand how you solve problems, it is important for us to record your thoughts in a cassette recorder; so, don't be shy or feel inhibited because your voice is being recorded.

Try to think aloud. The more you tell me what you are thinking, the better will be my understanding of your thought process. This must include thoughts that may seem to have nothing to do with the task in hand.

I shall be particularly interested in the first half of the solution : between starting to read the question and being able to start the written part of the solution. During this stage, you may be deciding about the meaning of the question, the relevant bits of knowledge if you know how to do it or not, and you may be planning out what to do. Since this phase does not normally appear in written solutions, I can only get it through a cassette recording.

After you solve these problems, answer the questionnaire. Please make sure you answer all questions in good detail. A part of the questionnaire is a test of the knowledge required in these problems.

The problems must be attempted BEFORE answering the questionnaire.

Thank you and best of luck!

DR. J. BAPAT.

C.I.T. Date:........................

Name: ....

Student in : (Tick one of the following boxes)

CHE 111	H.S.C.	T.O.P.
☐	☐	☐

PROBLEMS

As soon as you start reading each problem, start the cassette recorder in the RECORD mode and start thinking aloud. Stop the recorder when you complete solving the problem.

Problem 1: Write the structural formulae of :

1.1) Butanal

1.2) 1,2,3-propanetriol

1.3) heptan-3-ol

1.4) Cyclobutene

1.5) The aldehyde and the ketone with the formula C_3H_6O .

Problem 2: Write down the products obtained in the following reactions:

2.1) Catalytic reduction of pent-2-ene with H_2 .

2.2) Oxidation of cyclohexanol with potassium dichromate.

2.3) Reduction of methyl ethyl ketone.

2.4) $CH_3O^{\ominus}Na^{\oplus} + CH_3{-}Cl \longrightarrow$

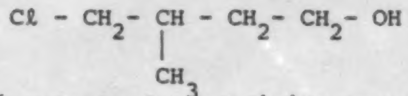
2.5) $\underset{(A)}{C_2H_2} \xrightarrow[\text{reduction}]{\text{careful}} \underset{(B)}{C_2H_4} \xrightarrow{HI} C_2H_5I$. (What are A,B & C?)

.../2

Problem 3:

3.1) With aqueous NaOH, C_3H_7I (A) gives C_3H_8O (B), which may be oxidised only to acetone.
Identify A and B.

3.2) When



$$\mathrm{C\ell - CH_2 - \underset{\underset{CH_3}{|}}{CH} - CH_2 - CH_2 - OH}$$

is warmed with dilute alkali, a cyclic compound containing oxygen is produced.
Suggest a structure for this compound.

3.3) An organic acid $C_2H_2O_4$(A) reacts with ethanol to produce $C_6H_{10}O_4$(B).
Identify the acid (A) and compound (B).

Problem 4:

Ethanal reacts with methanol initially to produce a compound (A) $C_3H_8O_2$. This compound reacts further with more methanol to produce compound (B) $C_4H_{10}O_2$. Water is also produced during the 2nd reaction.
Identify compounds A and B.

QUESTIONNAIRE and KNOWLEDGE TEST

Q.1. If you think you have been unsuccessful in solving any of these problems, state possible reasons by placing the correct number in the appropriate column.

Cause	No.
Lack of background knowledge.	1
Spending a lot of time on an incorrect solution.	2
Failure to grasp the significance of the information provided.	3
Cannot remember structures of organic compounds.	4
Any other reason (specify).	5

Problem	Cause (place only the correct no. below)

Q.2. Write the general formula for

2.1) an aldehyde

2.2) a ketone

Q.2. (continued).

2.3) an alcohol.

2.4) an alkene.

2.5) an alkyne.

2.6) an organic acid.

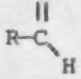
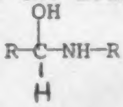
Q.3. Explain very briefly the meaning of the following terms;

3.1) Reduction.

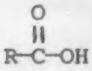
3.2) Oxidation.

3.3) Esterification.

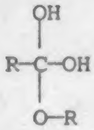
Q.4. How will the following pairs react to produce the reaction product given?

4.1)  and $R-\ddot{N}H_2$ Product: 

$R-\underset{\displaystyle H}{\overset{\displaystyle OH}{C}}-NH-R$

4.2) 

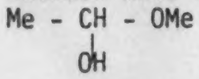
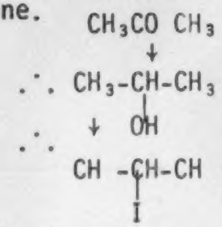
$R-\overset{\displaystyle O}{\overset{\|}{C}}-OH$

$+ \; R-\ddot{O}H$ Product: 

$R-\underset{\displaystyle O-R}{\overset{\displaystyle OH}{C}}-OH$

APPENDIX B

PSBTS RESULTS FOR THE SAMPLE

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
90	B.T. Hart	HOD	3.1	✓	B_1, C_1, C_2, D_2, B_3	✓	Starts $\bar{c}$ R-I + $\overset{\theta}{\text{OH}} \rightarrow$ R-OH & then says ∴ n-Pr-I. But then sees acetone & comes back to >-I.
			3.2	✓	B_1, C_1	X	One Cl used. Replaces Cl by OH. Then has trouble cyclizing.
			3.3	✓	C_2, C_3, B_4, C_2, B_1	✓	Logical approach. Oxalic acid + alcohol ∴ diester, etc.
			4.	✓	-	X	Knows RCHO & ROH. Then writes an ester. No, I'm wrong. Can't remember R^n between RCHO & ROH. It can be  $\text{Me - }\underset{\text{OH}}{\underset{\vert}{\text{CH}}}\text{ - OMe}$
91	D. Packham	Inorg. Lecturer	3.1	✓	C_2, C_3, C_2, Conservative focussing.	✓	Perfect logical approach. Starts with acetone.  $\begin{array}{l} CH_3CO\,CH_3 \\ \downarrow \\ \therefore CH_3\text{-}\underset{OH}{\underset{\vert}{CH}}\text{-}CH_3 \\ \downarrow \\ \therefore CH\text{-}\underset{I}{\underset{\vert}{CH}}\text{-}CH \end{array}$
			3.2	✓	B_4, B_4, B_1, C_2	✓	$\begin{array}{l} C\text{-}C\text{-}OH \\ C\text{-}C\text{-}Cl \end{array} \overset{-\,NaCl}{\underset{H_2O}{\rightarrow}}$ answer I guess that they join through OH & Cl.
			3.3	✓	C_3, C_2, C_2, C_3	✓	Gets oxalic acid. Then formula matching.
			4.	✓	C_3, C_2, B_4, B_1	X	Tries formula matching. Writes $CH_3\text{-}C\text{-}CH_2OH$ No not that. Then writes $CH_3\text{-}CH\text{-}CH_2 \downarrow$ No, give up.

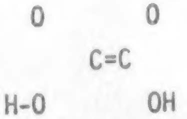
No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
92	Lawrence McCarthy	Technician	3.1	✓	B_4, C_1, B_4, C_3, C_2, C_2	✓	Logical. Starts $\overline{c}$ acetone. Counts atoms ∴ products.
			3.2	✓	B_3, A_1, C_2, B_1	✓	"I look for active part in the molecule. Then an educated guess.
			3.3	✓	A_2, B_4, C_1, C_3, C_2, C_3, B_4 C_2, C_2	✓	Logical. Since acid + alcohol ∴ an ester. Then checks formulae for fit.
			4.	✓	C_3, B_2, B_2	✓	"I'm really cheating here". First writes CH_3 COOMe. Then counts atoms & changes. Then does correct formula matching.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
01	Andrew Andreou	CHE 228	3.1	✓ 11/11	B_4, B_4, C_2	X	Just writes iodo-propane & propanol. Fails to use the info. from acetone.
			3.2	✓	-	✓	No transcript. Just the correct answer.
			3.3	✓	B_4	X	Gets oxalic acid, but then only forms 'monoester'. Only 1 line transcript.
			4.	✓	C_3, B_4	X	Cannot use the knowledge to use attack by -ÖH or $-\overset{O}{\overset{\|}{C}}-H$ just says, "Doesn't make sense".
85	Andrew White	CHE 228	3.1	✓ 11/11	A_1, C_2, C_2	✓	Logical approach acetone ∴ OH & -I
			3.2	✓	B_4, C_2, C_1, C_2	✓	Straight into inductive & deductive statements. Logical.
			3.3	✓	C_3, D_2, C_2, B_4, C_3	✓	Gets oxalic acid. Adds one mole of ethanol & verifies formula. Then adds another mole.
			4.	✓	B_3, B_4, C_3, C_2, C_2, B_2	✓	Logical start but wrong. Tries OMe, $+CH_3$ as leaving groups. Then comes to losing water. Hence correct formulae.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
60	Giovanni Della Penna	CHE 228	3.1	✓ 11/11	C_2, C_3, C_2	X	N-propanol & iodide. Acetone info. not used.
			3.2	✓	C_1, B_4, C_2	✓	Logical. Many inductive statements in this protocol.
			3.3	✓	C_3, C_2, C_1, C_3, B_4, C_2, C_3 D_1	✓	" "
			4.	✓	C_1, C_2, C_3, C_3, C_1, D_1	✓	" "
79	Peter Theodoropoulos	CHE 228	3.1	✓	C_3, B_4, C_2, D_2	✓	4 statements. Decides between 1-iodo & 2-iodo straight away. Logical approach.
			3.2	✓	B_4, C_2, D_1	✓	3 statements. 'Cl' will go off E H. ∴ structure is .... .
			3.3	X	C_3, B_3, B_1	X	Gets oxalic acid. Then resorts to random trial-error.
			4.	✓	B_2, C_2, C_3	✓	Doesn't know the chemistry but works it out correctly.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
16	Rodney Cram	CHE 228	3.1	✓ 11/11	?	✓	No transcript.
			3.2	✓		✓	Script book shows attack by electrons, etc.
			3.3	✓		X	Gets oxalic acid. No further material written.
			4.	✓		✓	
09	Phil Brewis	CHE 228	3.1	✓	C_3, B_2, C_2, D_1	✓	Logical approach. Initially thinks that RI is n-propul iodide but then changes his mind when he sees acetone.
			3.2	✓	A_1, C_3, C_2, C_1, B_3, C_1, D_2	✓	Initially gets Me OH but rejects this in favour of Me O Logical approach, although the basic knowledge reqc. to see that is not possible is not there. But considers 2 alternative approaches; something different to the CHE III students!
			3.3	✓	B_4, C_2, A_1, C_2, C_1, C_2, D_1	✓	Beautiful logical approach. Statement → inference → deduction → relation → check, etc. Conservative focussing.
			4	✓	A_1, C_2, C_2, C_2, D_1, C_2, C_3	✓	As above.

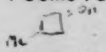
No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
71	Paul Segar	CHE 228	3.1	✓ 11/11	C_1, C_1, C_1, C_2, C_2	✓	Many inductive statements. Solves it from the C^+ ion angle. Also SN, & SN_2. No formula matching.
			3.2	✓	B_4, B_4	✓	'Focus gambling'? Guessed that attack would be at Cl & by OH.
			3.3	✓	C_1, C_2	✓	Diacid ∴ diester ∴ oxalic & dioxalate.
			4.	✓	-	X	No recording. "I give up on this".
53	John Nicolussi	CHE 228	3.1	✓ 11/11	C_3, B_4, C_2, C_2	✓	Systematic trial-error.
			3.2	✓	B_2, C_2, C_2	✓	Logical approach.
			3.3	✓	C_3, C_3, C_1, C_3, B_2	✓	Logical approach. B_2:systematic trial & error. Matches di-acid formula & then diester.
			4.	✓	C_1, B_3, C_3, C_3, C_2, C_1, C_3	✓	" "

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
06	Bernstein, Bryant	CHE III	3.1		5C3	X	Acetone? Can't make it with 3 bloody carbons!" No answer.
			3.2		2B1, 3A1, 3C3, B4, C2		Guesses alkali "takes off the hydrogen" & systematically follows it through (molecule could bend, chlorine comes off easily, etc.)
			3.3	X	2C1, C3, C2, B3, 4B2, A2, B1	X	Recognizes 2 acid groups but draws:  O O C=C H-O OH Can't name it "How do you get a double bond in the middle of that mess?"
			4.	X	2B2, 2B4, B3, 2B1, 3C1, 11C3	X	Assumes carboxylic acid groups and fits structure to formula.
63	Pitrone, Tina	CHE III	3.1	X	5 x A1, 2 x B1 RANDOM	X	Doesn't know formula for acetone. Doesn't recognize specific data given.
			3.2	X	5 xB1, C2, 4 x C3, A1 RANDOM	X	Trys to determine how reaction will occur.
			3.3	X	2 x C3, C2, A1	X	Can't name oxalic acid. Trys to match formula to structure.
			4.	X	C3	X	Doesn't know "a1". One statement only. In Questionnaire states "trying to get all the information together" is the problem. Plus lack of background knowledge.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
64	Raponi, Mauro	CHE III	3.1	✓	3 x D1, A1, 5 x C3, A2, B4	X	Matches formula to structure → n-propyl iodide & propyl ketone
			3.2		B4, B1, C3	X	Just reads problem.
			3.3		B3	X	Only one statement and gives up.
			4.		6 x C3, B1, 2 x B3, 2 x B4 D1	X	Convinced its an anhydride. Answer is structure for ester. Matches formula to structure.
55	Northeast, Eric	CHE III	3.1	X	C2, 2 x C3, 2 x D1, B4	X	Matches formula to structure. Makes no use of oxidation data n-propyliodide, propanol (no structure).
			3.2	X	--	X	Dediced to skip problem. No statements made.
			3.3	X	2 x A1, 2 x B4, D1, C3	X	Matches formula to structure.
			4.	X	2 x B4, C3, B3	X	Recognizes compound is a ketone. Trying to match formula to structure.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
57	Paras, Senen Joel C.	CHE 111	3.1	✓	5 x C3, B2, D1, A1, B1	X	Matches formula to structure → propanol for A. Propane for B Knows definition of oxidation.
			3.2	✓	8 x C3, 3 x B4, C1, 2 x A1	X	Begins by attempting to see how reaction could occur but finally only matches formula to strucuture
			3.3	X	6 x C3, 2 x B3, 2 x B4	X	Matches formula to structure (seems to be getting frustated) Ethanoic acid no structure.
			4.	✓	2 x A1, 3 x B4, B x C3, B1	X	Matches formula to structure.
58	Parsell, Dale	CHE III	3.1	✓	--	X	n-Butyl iodide as name but structure given is n-propyl iodide. B = name is butanal, no structure NO TRANSCRIPT.
			3.2	✓	--	✓	NO TRANSCRIPT.
			3.3	✓	D1, C3	X	Can't name oxalic acid. Only 2 statements. Structure of oxalic acid correct.
			4.	✓	A1, 2 x B2, C3, B4	X	Only 4 statements (17 words total)

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
65	Rausa, Joe	CHE III	3.1		D1, 2 x C3, B1, B3, B4	X	Just matches formula to structure ie: n-propyl iodide & n-propanol.
			3.2		C3, B1	X	3 statements, just reads problem
			3.3		A1, C2, C1, 2 x C3, B2	X	" " " "
			4.		A1, 2 x B1, B4, 2 x C3	X	RANDOM trial & error.
							In questionnaire states "cannot assimilate information"
67	Reubenicht, Mark	CHE III	3.1		2 x B1	X	Only 2 statements viz guesses aqueous means water guesses I means iodine.
			3.2		B2, C3, A1, 2 x B1	X	Trys to match formula to structure
			3.3		B2, B3	X	3 statements. Doesn't know ethanol
			4.		B3, B4	X	Recognizes alcohol, decides to skip problem.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
12	Thierry Can,	CHE III	3.1	X	-	X	No tape recording either, tape empty.
			3.2		-		
			3.3		-		
			4.		-		
66	Recinnella, P.	CHE III	3.1	X	-	X	No recording. Writes n-propanol & iodide
			3.2	X	-	X	No recording (just reads question)
			3.3	✓	B4	X	Just says, "It would be R-COOH"
			4.	✓	-	X	Gambling, to match formulae. No recording.
56	Nyunt, Victor	CHEIII	3.1	✓	-	X	Nothing on tape except mumbling, answer given is propyl iodide & propanol.
			3.2	✓	-	X	- -
			3.3	X	-	X	Just tries to match formulae.
			4.	X	-	X	- -
52	Mouncey, Terry	CHE III	3.1	✓	-	X	No tape recording. Structures written are n-propanol & n-propyl iodide.
			3.2	✓	-	X	'Cl' has been recmoved. Structure written is: 
			3.3	✓	-	X	Gets oxalic acid & the mono-ester
			4.	✓	-	X	Not attempted. Knows CH_3CHO & CH_3OH

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
38	Ron Hubeck	CHE III	3.1	✓	2 x A1, C2, 2 x C3, B2, D1		Logical approach, systematic trial and error.
			3.2	✓	A1, A2, C2, B4, D1	X	Has matched the formula correctly but has problem $\bar{c}$ 'set'. Cannot think of 'O' going into the ring. .'. writes OH CH$_3$
			3.3	✓	2 x B4, B1, C2, 2 x C3, D2		
			4.	X	C2, C3	X	Doesn't know ethanal.
40	Jirik, Stephen	CHE III	3.1	X	2 x C3, B4	X	Does not know 'acetone' .'. sticks to n-propanol & propyl iodide
			3.2	✓	B4, C3	X	Just 3-4 statements. Writes but no methyl group.
			3.3	✓	B4, C2, C1, C3, D2	X	Comes very close. Gets oxalic acid and makes COO COOH
			4.	✓	—	X	2-3 statements - gives up.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
32	Chris Hall	CHE III	3.1	✓	B1, C2, C3	X	Gambling, just writes the structural formula for the molecular formula given (comes up $\bar{c}$ wrong answer).
			3.2	✓	C1, C2, B4	X	→ makes the correct-deduction (but gambled one) that C1 has got to go
			3.3	✓	B1, 2 x C1, C2, B4	X	Gets the acid right. Then just adds groups to match the formula of B. No logical thought.
			4.	✓	A1, 2 x B1, C3, B4	X	Random attempts to fit structures to M.F.
30	Mark Graesser	CHE III	3.1	✓	-	X	Just reads
			3.2	✓	-	X	No recording
			3.3	✓	-	X	" " _ garble
			4.	X	B1, B4	X	Random attempts at matching structural formula.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
31	Paul Haines	CHE III	3.1	✓	B1, B4, C2	X	Just tries to match the formula No thought given to acetone.
			3.2	X	B1	✓	Just gambled & came up with correct structure.
			3.3	✓	A2, 3 x B1, 2 x C3	X	Comes up with oxalic acid structure just by matching - gambling.
			4.	X	B1, C3	X	Gambling - just matching the formula.
34	Adrian Hegedus	CHE III	3.1	✓	A1, B2, B4, C2, C3	X	Cannot work out the $>=O \rightleftarrows \rightarrow CHOH$ relationship.
			3.2	✓	-	X	2-3 statement. Not attempted.
			3.3	✓	A1, B1	X	" " "
			4.	✓	B1	X	" " "
35	Duong Ho	CHE III	3.1	✓	-	X	N.A. (Not attempted)
			3.2	✓	-	X	No recording
			3.3	✓	-	X	" "
			4.	✓	-	X	" "

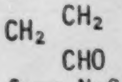
No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
13	Russell Christian	CHE III	3.1	X	B4	X	Only 3 statements
			3.2	X	B4, A1, C1, C3	X	~ 6-8 statements too many false assumptions.
			3.3	✓	B4, B1	X	Reads & then immediately draws the wrong inference
			4.	X	B4, B1	X	
15	Mark Coleman	CHE III	3.1	✓	B4, B1, A1, C2	X	3 statements. Trial-error Inference pattern observed.
			3.2	✓	A1, B4, C2	X	Realises that 'C1' must go. 3-4 statements.
			3.3	X	-	X	Doesn't know what 'ol' is.
			4.	X	-	X	Lack of basic knowledge. Just reads the problem.
17	Lawrence Dean	CHE III	3.1	✓	A2, B2, B4, C2	X	~ 8 statements
			3.2	✓	A2, B1, B4, C2	X	Takes a guess ('random trial')
			3.3	✓	B2, C2, 2 x C3, B4	✓	-
			4.	✓	2 x B4, 3 x C3, C2, B1, B2	X	Tries to match the formula without worrying about the reaction of functional groups, i.e. his products are: gambling

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
02	L. Ken Arnolda	CHE III	3.1	✓	Random trial and error B1, B4	X	Only four statements on the cassette recorder.
			3.2	✓	" " " B1	✓	" Guesses correct structure
			3.3	✓	" " " B1	X	"
			4.	X	--	Not attempted	--
07	G. Bingley	CHE III	3.1	X	-	Not attempted	--
			3.2	X	-	"	--
			3.3	X	B1	X	Only 4 statements
			4.	X	B1	X	Only 6 statements
10	R. Bucher	CHE III	3.1	✓	A1, 2 x B4	X	R-I → R-OH deduced
			3.2	✓	--	X	Only ∿ 5 statements. Just reads the problem over & over
			3.3	✓	C1, C2, B1, B1, B4, D2	✓	∿ 20 statements. Got $\begin{array}{c}\mathrm{COOH}\\ \vert\\ \mathrm{COOH}\end{array}$ also the ester.
			4.	✓	A1, B1	X	Statements of the type, "I can't see how that happens." (He is stuck).

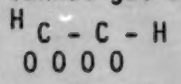
No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
43	Ivan Kalikov	CHE III	3.1	X	B2, 2 x C2, C3	X	Does not know ketones could not (even) work out the structure of $CH_3CH_2CH_2OH$
			3.2	✓	A1, C3, C2, B3	X	Writes OH. Has lost the methyl group.
			3.3	X	B1, C2, C3	X	Arranges random structures to fit the formula.
			4.	✓	2 x C3, B4, B1	X	Does not know esterification. Random trial and error.
50	Peter Meggs	CHE III	3.1 3.2 3.3 4.	} X	X	X	No material of any value of consequence recorded.
49	Angelo Markon	CHE III	3.1	✓	C3, C2	X	3-4 statements. Goes to fit structural formula only. Gets n-propyliodide → porpanol.
			3.2	✓	C3	✓	Transcript too short.
			3.3	✓ (?)	-	X	Gets $\begin{matrix}\mathrm{COOH}\\ \vert\\ \mathrm{COOH}\end{matrix}$ Then just tries formula fit. Does not know esterification.
			4.	✓	-	X	No material of consequence recorded.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
48	Trinh Luu	CHE III	3.1	✓ 11/11	-	X	Not attempted
			3.2	✓	B4, C3	X	Writes = O. Gambling on "cyclic compd. containing oxygen" only 3 statements.
			3.3	✓	A1, B4, C2, C3, D1	✓	Classic logical approach. Only 6-7 statements. No mumbling like in previous problems.
			4.	✓	A1, C3, C1, C3	X	Starts c̄ wrong deduction, i.e. alcohol + aldehyde → ester
27	Paul Freeman	CHE III	3.1	✓	B4, C2	X	4 statements. Wrong deduction. Since it goes to acetone, it must be 3^o alcohol.
			3.2	✓	B4, B2	X	Thoughts not recorded. Was on the right track. "off Cl, whip off H. But also removes OH.
			3.3	✓	2 x B4	X	Thoughts not completely recorded. Right track. Says A is dicarboxylic acid, B is ester.
			4.	✓	B4	X	Aldehyde + alcohol → carboxylic acid.

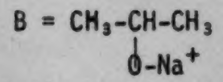
No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
61	Maritta Pfauder	CHE III	3.1	✓	A1, C2, C2	X	Wrong deduction. 1^{o} alcohol $\xrightarrow{(O)}$ ketone
			3.2	✓	A1, B2, B4, C2	✓	4 statements. Logical approach
			3.3	✓	B4, C1, C3, B2, C2, C3	X	Gets oxalic acid. Know acid + alcohol → ester. Mucks up ester structure.
			4.	✓	A1, B1, C3, B1	X	Random trials to fit structures.
74	Phillip Stuckley	CHE III	3.1	X	-	X	No tape recording
			3.2	✓	C1, C2	✓	" " " except one statement.
			3.3	X	-	X	Does not know E OH
			4.	X	C1, C2, C3, B1, B1	X	Random attack.
70	G. Scott	CHE III	3.1	X	-	X	Not recorded.
			3.2	✓	-	X	" "
			3.3	✓	B4, C3, C2, B4	X	Gets $\begin{array}{l}\text{COOH}\\ \vert \\ \text{COOH}\end{array}$ by a deductive approach.
			4.	✓	-	X	Not recorded.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
44	Bernard Kuran	CHE III	3.1	✓ 11/11	C1, C2, C3, B2, D1	X	Cannot recognize that $>\!\!=$ O must come from sec-alcohol. Otherwise logically attempted.
			3.2	✓	B1, B4, C2	X	Writes structure  $CH_2\begin{smallmatrix}CH_2\\CHO\end{smallmatrix}$ Knows S_N (Na will form NaCl) says 'a branch $\bar{c}$ CH_3 on it' but probably forgot to write that.
			3.3	✓	B4, C2, B1	X	Gets 2xCOOH. But cannot under stand how they can be connected together. Set, "COOH ought to be attached to something."
			4.	✓	C3, B1	X	Gets the formula of Ethanal wrong. Then random trial/error Trying to match formulae.
54	M.P. Lo Nigro	CHE III	3.1	X Does not know acetone.	B4, C3, C2, C3, B1, B4	X	Very long transcript. Gets stuck with acetone structure.
			3.2	✓	C3, B1, B4, B1, C3	X	Random trial & error to fit formula to structure somehow thinks the cyclic structure must have a double bond.
			3.3	✓	-	X	No transcript. Gets oxalic acid. Then just tries matching formulae.
			4.	✓	-	X	Random formula matching.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
76	Lynn Tan	CHE III	3.1 3.2 3.3 4.	} X	} X	} X	Mostly mumble and "I can't do it."
81	Garry Thurley	CHE III	3.1	✓	B4, C1, B4, B1	X	Comes with n-propanol & iodide cannot use info. re acetone.
			3.2	✓	C2, B4	X	Me is the answer. Starts $\bar{c}$ HCl taken off to neutralize alkali.
			3.3	✓	C2, C3	X	Gets oxalic acid. But then just formula matching.
			4.	✓	B1	X	2 statements. Random formula matching.
84	Peter Vass	CHE III	3.1	✓	x	X	Not attempted, "I don't understand it."
			3.2	✓	B4	X	Just reads 2-3 times. N.A.
			3.3	✓	C2, B1, C3, C3, B1	X	Gets oxalic acid. Then simply formula matching.
			4.	✓	B4	X	Reads 2-3 times. N-A
87	Kim Wong	CHE III	3.1 3.2 3.3	} X	} X	} X	N-A
			4.	✓	B4, B2, B4	X	Mere formula matching & 3-4 pages of continuous nonsensical talk.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
86	Adam Wittmer	CHE III	3.1	✓	B1, C3	X	Writes acetone as MeOMe but knows ketone structure. Gives up.
			3.2	✓	B1, B4		5-6 statements 'Chloride has been taken away. 'You could take the Cl with the alkali.' Then suddenly, 'I've got it'.
			3.3	✓	B2, C3	X	Cannot get oxalic acid. Writes  $^{H}\underset{O\;O}{C} - \underset{O\;O}{C} - H$ & then further formula matching.
			4.	✓	B4	X	CH_3CHO & CH_3OH known. N-A

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
18	De Felice, Michael	CHE III	3.1	✓	3A1, 2D1, 2B3, B2, 5C3, B4	A x B	A = 'propyl iodide' B = propan-2-ol or 3-propanol.
			3.2	✓	2B2, 2B4, 3C3, D1, 2B1, 3A1	X	"What's the alkali do?" Gives up.
			3.3	✓	8C3, 10A1, 3B4, 3B3, 2B2, 2A2, 2C2, C1, D1	BX	Draws structure of oxalic acid but cannot accept its existence. "How can it be a bloody double acid?" Recognizes ester formation but can't do it (presumably the 2nd COOH upsets him)
			4.	✓	16C3, 12A1, 3B4, 10B1, 3B2, A2, C2, D1, B3		Overall RANDOM. Considers A is an acid and B is an ester but does not correct this assumption despite being unable to fit a structure to the formula.
21	Dixon, Brett	CHE III	3.1	✓	3A1, B4, 2D1, 3B2, 2C2, B3	✓	SYSTEMATIC
			3.2	X	A1, C3	X	2 statements only
			3.3	X	4C3, B3, 3C2, 2D1, 2B2, 2B4, A1, C1, B1	X	"What does organic acid do with alcohol". Could not define esterification. ("Breaking down esters.")
			4.	X	C2, C3		Recognises aldehyde & manipulation A 3rd statement is "Double bond goes back there" C3?

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
22	Dore, Mike	CHE III	3.1	✓	C1, 3C2, 2B4, 5C3, A2, 3B2 2D1, 4A1, D2	✓	"What's acetone?" then "must be a ketone". Fits structure to C_3H_8O then checks oxidation will give a ketone. SYSTEMATIC.
			3.2	X	2A1, B4, C3	X	"Now what would (dil. alkali) do?" Only 4 statements.
			3.3	X	2A1, 2B4, 5C3, 2A2, B1, D1, B3	A ✓ B x	Can't accept $C_2H_2O_4$ is an acid then sees its a "double acid". Trys to fit structure to formula of B. (Did not give a definition of esterification.)
			4.	X	3C2, B4, C1, A1, B3, 2B3, 2B1, B2, A2		Recognizes "al". Tries to react the alcohol and aldehyde.
23	Dosser, Paul	CHE III	3.1	X	No transcript	A ✓ B x	 B = $CH_3-CH(O^-Na^+)-CH_3$ Sodium propanate. (In questionnaire did not answer definitions of oxidn., redn. & esterification.)
			3.2	✓	B3, B4, A1, D1, C3	X	Recognizes "alcohol attacks chlorine" but gives OH as
			3.3	X	C3, B2, B4		Only 2 statements and the phrase "so, reducing ..."
			4.	✓	5C3, C2, 3B2, 3A2, 3A1, 3B4, D1, B3	X	Trys to fit structure to formula.
				Questionnaire: "Ability to think straight is hindered - disturbances and annoyances."			

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
29	Griffin, Patrick	CHE III	3.1	✓	3B4, 2C2, 2C3, B3, B1, A2	X	"What's acetone?" (In questionnaire gives ketone as R-O-R $\genfrac{}{}{0pt}{}{O}{H}$) A = propyl iodide (no structure) B = propanal.
			3.2	✓	A1, 2B4, A2, 2C3	X	Starts off "lose this, lose that". Answer = ∿ 5 statements.
			3.3	✓	C1, 4B4, 19C3, 6A2, 6B1, 2D1, 2B2	A ✓ B x	Can't name oxalic acid. Assumes B is an ester, a diester then considers polymerisation. For B fits structure to formula after each assumption.
			4.	✓	2C2, 3B3, 5B4, 2B1, 10C3, 2A1, 2B2	X	Recognizes aldehyde and alcohol reacting. Trys to fit structure to formula using methanol as fragment to be added.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
75	Swinbank, Alison	CHE III	3.1	✓	Blank tape	X	No answer
			3.2	✓	" "	✓	-
			3.3	✓	" "	X	Only HOOCCOOH as answer. No structure for B.
			4.	✓	" "	X	An ester as answer ("dimethyl ester")
05	Berecic, Doug	CHE III	3.1	✓	2B4, B2, A1, 2C3, 2D1, B3	X	"Propan iodide & Propanol". No structures. Fits name to formula. (Only name as answer).
			3.2	✓	2B3, 6B4, 5A1, 8C3, 2B2, B1	X	SYSTEMATICALLY fits a structure assuming 1 H is lost. Cl is in proposed structure. Cl O CH_3
			3.3	✓	7C3, A1, B4, B2, 2D1, 3B1	X	Oxalic acid for A. Assumes B is a dioc acid also, fits "hexandioic acid" to formula. NB $C_2H_2O_2$ structure reminds him of something so he goes back to 2.5 & correctly identifies ethyne & ethene.
			3.4	✓	3B3, 5B4, 2B1, 7C3, 5D1, A2	X	Assumes both are diols & fits name (structure) to formula. Only name is given as an answer. Read ethanol, later corrects this & states "can't get an acid from that" thereby eliminating "acid" as a possible solution.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
33	Haviaridd, Paul	CHE III	3.1	X	3B4, C3, B1, 2D1	X	Propyl iodine & propanol. Fits structure to formula. For B, guesses an alcohol.
			3.2	X	-	X	Only stt. "Don't know how to do.."
			3.3	X	2B4, D1		Assumes 2 alcohols = HO=C-C=OH Does not check if it fits formula.
			4.	X	2B4, B1, 2D1	X	Assumes 2 alcohols on end = 1,3-propanol & 1, 4-butanol. Does not check if fit formula.
36	Ho, Foo Nin	CHE III	3.1	X	C3	X	"What is the A? Can't do it"
			3.2	X	Question is not attempted	X	Not appear on transcript
			3.3	X	" " "	X	
			4.	X	" " "	X	Says several times "so hard", seems anxious to finish.
62	Phillips, John	CHE III	3.1		B4, B3, 2D1, C1, B1	X	"Propyl iodide" & "propanol"
			3.2		4C3, 2B4, 4B1, 2B3, C2, B2	X	Guesses ether oxygen or alcohol "Stab in the dark" for alcohol -cyclopentanol
			3.3	X	2B4, 9C3, 2D1, B3	Av Bx	4 oxygens in B = "not unlike the first one (A) = dioc acid. = hexandioc acid. In questionnaire "Don't think diocs right"
			4.	X	11C3, 3B3, 4B1, B4	X	Not sure what ethanal is (structure drawn OK) "Forgotten the basics". Randomly tires various functional groups to fit structure to formula.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
89	Kevin Woodward	CHE III (P/T)	3.1	✓	B_1, B_2, C_3, C_2, B_4	✓	Starts systematically but then is lost. Reverts to 'Focus Gambling' by using acetone as a (+ve) instance and works backwards.
			3.2	✓	C_2, B_1, B_1	✓	'Focus Gambling' again. Focusses on cyclic oxygen compounds & then tries to fit structures. Gambles successfully on losing HCl.
			3.3	✓	B_4, C_3, C_1	X	Set. Cannot get oxalic acid structure. Writes COOH C-H 0 0 Knows acid + alcohol → ester but cannot use it.
			4.	✓	B_1, C_2, C_3, B_1, C_3	X	Does not know Ethanal. Random trials to match formulae.
78	Linda Thatcher	CHE III	3.1	✓	C_3, B_4	X	Ignores 'acetone' in the problem just matches formulae to propanol and propul iodide.
			3.2	✓	C_3, B_4, B_4, C_2, C_2, C_2	✓	Focus Gambling. Recognizes loss of HCl & then uses that to do 2-3 guesses to arrive at the correct structure.
			3.3	✓	B_1, C_3, B_4, C_3, C_3, C_3 Random guessing	X	Gets oxalic acid but then just formula matching.
			4.	X	B_1, C_3, C_3	X	Random formula matching.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
45	Laird, Fiona	CHE III	3.1	X	4C3	X	Doesn't know 1. Just reads Q.
			3.2	X	C3	X	Just reads question.
			3.3	X	2C3	X	Just reads question. Doesn't know ethanol.
			4.	X	B4, B3, C3	X	In her words "All I need is the formula for ethanal and methanol." Gives up on all questions.
83	Van Dupin, Gary	HCS	3.1	✓	No tape	X	Iodopropyl & methyl ethyl ether
			3.2	✓	" "	X	
			3.3	X	" "	X	Not define "esterification" Oxalic acid structure OK. No answer for B.
			4.	X	" "	X	Many attempts by look of answer. Probably matching structure to formula.
25	Fernandez, F.J.	HSC	3.1	X	Only comment "3.1's out"	X	Not attempted.
			3.2	X	" " "3.2's out"	X	" "
			3.3	X	" " "3.3's out"	X	" "
			4.	X	" " "4's out"	X	" "

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
39	Jayamaha, Anthony	HSC	3.1	✓	2D1, B3, 5B4, 2B1, 7C3, 2A2.	✓	Iodopropane & propan-2-ol. Considers question has a mistake because "acetone only has 2 carbons". Fits structure to formula.
			3.2	✓	21C3, 4B1, B3, 2B4, B2	X	Fits structure to formula.
			3.3	✓	3B3, 2C2, B1, D1, B4	✓	"What the hell is that?" when looking at $C_2H_2O_2$ Names B-Butyl diethanoate, ester.
			4.	X	2C2, 9C3, 2B3, 3C1, 2B1, B4, A1, B2	X	"God, I haven't got a clue". Considers an "addition compd." and fits structure to formula to A & B as diols.
46	Leitch, Jane	HSC	3.1	X	-	X	No answer. Only 3 stts. Acetone. Don't know & Don't know
			3.2	X	B1, B4, 5C3	X	Assumes benzene ring containing oxygen is produced. Answer is:
			3.3	X	7C3, B3, B1	X	"What's ethanol?"
			4.	X		X	Reads 1st 4 words of problem then 2½ mins silence before tape turned off. (i.e. background noise only)

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
37	Holvast, Jacob	HSC	3.1	✓	B3, B4, 2B1, B2, C3, D1	X	Propane iodide & propanal. Systematically firs structure to formula A. Simply states what B is.
			3.2	✓	3B4, 3C1, 7C3, 3A1, 3B1	X	Can't decide if reagent is 1^{o} or 2^{o} alcohol. "It looks like the hydroxy group will push out the chlorine. Don't know why this happens. Fits structure to formula.
			3.3	✓	B3, 2C1, 5C3, 3B1, 2B4	✓	"Interesting structure" for oxalic acid. Recognizes B is an ester but has no idea of its structure.
			4.		B1, 2D1	X	A = "aldehyde" B = "ester"
08	Bosa, Lydia	HSC	3.1	✓	2B2, 4C3, D1	X	Monoiodopropane & propanol. No transcript for A. For B, SYSTEMATICALLY fits structure to formula.
			3.2	✓	C3	X	Reads question twice more and counts. No answer.
			3.3	X	2B2, 15C3, 7B1, B3, D1	X	"I've never seen anything like it" Gives up on A. RANDOMLY tries various functional groups to fit structure to formula B without success & gives up. RETURNS TO PROBLEM. "Where'd all these oxygens come from?"
			4.	X	10C3, 2B1, 2C1	X No answer	"If only I knew what a ketone was!" (She has no answer for aldehyde, Ketone in Questionnaire.)

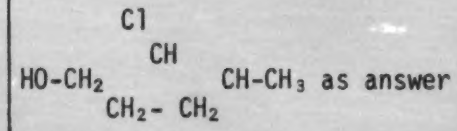
No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
26	Freeman, Maurice	Top	3.1	✓	No transcript	X	Propan-2-ol structure drawn.
			3.2	X	" "	X	No answer
			3.3	X	" "	X	No answer only COOH scrawled down.
			4.	X	B3, C1, B1	X	No answer but recognizes "al", stt. "they want a reduction of an aldehyde".
28	Fung, Yat Man	Top	3.1	✓	No transcript	X	No answer
			3.2	X	" "	X	" "
			3.3	X	" "	X	" "
			4.	X	" "	X	" "
03	Ho, Kimba	Top	3.1	✓	4C3, B1	X	"What does it mean?" Just reads question, answer was $C_3H_7I \rightarrow C_3H_7 \rightarrow C_3H_8O$
			3.2	X	C3, 2A1, 2B1	X	No answer. Fitting structure to formula?
			3.3	X	4C3, 5B1, 2A1	X	Fitting structure to formula. Did not answer "esterification" question in questionnaire.
			4.	X	8C3		Answer is $CH_3CHO + CH_3OH \xrightarrow{H^+/Cr_3O_7} C_3H_8O_2$ $CH_3CH\ O + CH_3CH_2OH \underset{H^+/Cr_2O_7}{\quad} -C_4H_{10}O_2$ Just reading question.

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
68	Saracoglu, Ali	Top	3.1	✓	A1, B4, 4C3, D1	X	"A = n-propyl iodide B = ethyl methyl ketone $CH_3CH_2OCH_3$" "a) is propane" as answer in transcript.
			3.2	X	-	X	Answer "4-butyl chloride" Just read question.
			3.3	X	5C3, 2A1, D1, C2, B4, B1, A2	X	"Benzenoic acid - C_6H_{10} is benzene" Fits structure to formula.
			4.	X	-	X	"I'll come back to that later" but doesn't.
69	Saracoglu, Mehmet	Top	3.1	X	2A1, 4B4, 2B2, 2D1, B1	X	A = 'propoidone' B = 'propanol' Systematically fits structure to formula. No reference to oxidation data.
			3.2	X	2B4, 2A1, D1	X	"Cyclo-3-methyl propanol"
			3.3	X	2C3, A1, 3B1	X	A = ethanal, B = hexanol Random guesses. Doesn't appear to know general formulae.
			4.	X	B2, B4, 2A1, 2B1	X	O_2 => acetic acid => ester. Intends to come back to it but doesn't.
				"Couldn't concentrate because everyone was talking."			

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
73	Staunton, Stephen	Top	3.1	✓	No transcript	X	A = $CH_3CH_2CH_2I$ B = $CH_3CH_2CH_2OH$
			3.2	✓	3C3, B1	X	Random - "I'll just go 5 in a circle .. with an OH off it" and fits structure to formula.
			3.3	✓	B3, 13C3, 4B4, C1, 3A1, 3B1, A2	X	Fits structure to formula "HOOC-COOH + $CH_3CH_2OH_{\downarrow}$ H $COOCH_3CH_3OOCH$" as answer.
			4.	X	2B3, 8C3, 5B1, B2, B4, 2A2	X	Methanol ⇒ alcohol ⇒ carboxylic (B1) acid reacting to give ester. Realizes his error, then "maybe its an alcohol, ketone, etc. Fits structure to formula.
80	Thomas, Neale	Top	3.1	✓	B4, C2, 2D1, 4C3, B3	A x B ✓	A = "n-propyl iodide"
			3.2	✓	B4, 3B1, 2C3	X	Random - "4 or 5 carbon ring could be 4C".
			3.3	X	B3, 5C3, 3B1	X	Fits structure to formula.
			4.	X	2B4, B1, 3C3, 2A2, B3	X	Fits structure to formula.
82	Tlas, George	Top	3.1	✓	5A1, 4B4, D1, C3, B3	X	"Propane iodide" &"n-propanol" Systematic.
			3.2	✓	5A1, 4B4, B1, C3, D1	X	Assumes "it contains a chloride so must be a chloride".Systematic.
			3.3	X	B4	X	Only one statement & "will skip" as "not too sure".
			4.	X	B3, 2B4, C3		Recognizes aldehyde & draws its structure. Decides to skip 4.

2

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
42	Karayiannakis, Con	Top	3.1	X	5C3, 3B3, 2B1, B4, B2, 3A1	X	No answer. Just reads question. Systematic plan of attack.
			3.2	X	-		No answer. Phrase "dilute alkali" underlined. "I don't understand it" is only statement.
			3.3	X	2B4, B3, 3C3, 2A1, C2, 2B1, 2A2	X	"What can it (A) be?" "What's A" Considers can't be ester or ether "don't know if referring to A or B)
			4.	X	7C3, 3B3, B1, 3A1, 5B4, A2, D1	X	A = "propane esther" B = "butane esther" } as answer Reads "ethanol". Determines class (ester) of compd.
46	Luck, Peter	Top	3.1	X	No transcript	X	A = "iodo-propane"
			3.2	X ?	" "	No answer	Answered Q1 OK but no attempt on Q2 - 4. Knows general formulae.
			3.3	X ?	" "	"	
			4.	X ?	" "	"	
51	Memed, Zoran	Top	3.1	X	-	No answer	Reads question, "means nothing."
			3.2	X	-	" "	"Oh, the futility of it"
			3.3	X	-	" "	"Once again stumped"
			4.	X	-	" "	"Stumped again"
					4. Reads question, makes statement and gives up. Only question answered correctly (out of 7 attempted) was definition of oxidn. and reduction and general formula of aldehyde. "Due to lack of background knowledge."		

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
04	Baksheev, Con	Top	3.1	✓	3B4, 3C3, A1	X	Recognizes a 2^{o} alcohol but can't seem to use this inform.
			3.3	✓	10C3, B4, 3B1, 2A2	X	Fits structure to formula. Some trouble naming.
			3.2	✓	No transcript	X	 Cl CH $HO-CH_2$ $CH-CH_3$ as answer CH_2-CH_2
			4.	✓	4B4, 2B3, C3	X	"Aldehyde with alcohol gives acid."
14	Cochrane, Danny	Top	3.1	✓	2D1	X	2 statements only - "A will be propanene iodide and B propanone."
			3.2	✓	B4, B1, A1	✓	Assumption CH_2CH CH_2CH_2 present => O is on CH
			3.3	X	2B3, 2B1, A1, 2A2, C3	X	Systematically fits structure to formula C_6 => hexan $\bar{c}$ $H_{10}O_4$ => can't be al, ol or yle.
			4.	✓	2B4, 2C3, 2B1, B3, D1, A1	X	C_3 => propan => propanone but does not check if it agrees $\bar{c}$ formula. Got question on mechanism correct.
20	Ditchfield, Rodney	Top	3.1	✓	Tape is blank	✓	
			3.2	✓		X	No answer.
			3.3	✓		X	
			4.	X		X	

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
72	Starr, Philip	Top	3.1	✓	2D1, 2B4, A1, C3	✓	A = "iodopropane" no structure. acetone => 2^o alcohol. Strategy.
			3.2	✓	3B4, A1, C3, D1	X	Decides a "pentane something" $\bar{c}$ 2 OH's. But decides its wrong and only has 1 OH.
			3.3	✓	3C3, 4B1, A2, B4	X	States "2 COOH" but "seems highly unlikely." Can't accept existence of oxalic acid. Considers an ester but can't get structure to fit formula.
			4.	✓	2B4, 4C3, 2B3, 5B1, 2D1	X	Considers various classes viz ether, acid, ester & fits methyl ethyl ester to A. Fits structure to formulae. Recognizes aldehyde, alcohol.
88	Wood, Peter	Top	3.1	✓	2B4, 4A1, 4C3, B2, 2D1	✓	Ketone => 2^o alcohol => 2^o alkyl halide. Systematic.
			3.2	✓	B2, 2B1, 2B4, 2C3	✓	"What's alkali" so looks at Cl => "the HCl will go."
			3.3	✓	4B4, 3C3, 2D1, A1	✓	Recognizes ester formation immediately. Some trouble naming A & B.
			4.	X	12C3, 5B4, 2B2, D1, 2A1	X	Recognizes C = 0 reactis with alcohol & gives ester an answer. Assumes B is an ester and tries to fit structure to formula.
			This student has informed all those around him of the answer to Q3.3 even though he doesn't know if it's right. (Referrring to oxalic acid.) He knows that B must be an ester.				

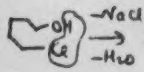
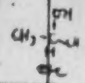
No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
11	Carinci, Renato	TOP	3.1	✓	3B4, 2B3, C2, 9C3, B2, A1	X	No answer for A. B, n-propanol. Recognizes OH^{θ} attacks. Fits structure to formula.
			3.2	✓	-	X	Only 1 stt. "Lack of background knowledge".
			3.3	✓	8C3, B2, C2, B1, B4, B3, D1, 5C3	X Cheats	Considers its an ester or aldehyde. Then CHEATS & is told a double ester. Ethyl dimethanoate. 2nd line refers to fitting structure to name. Also told $(COOH)_2$ for A.
			4.	X	2A1	X	Recognizes class of compd. NB Ethanal as CH_3CH_2CHO
19	De Marchi, Nic	CHE III	3.1	X	4B4, 5B2, C2, 6C3, 2A1, A2 D1.	X	n-propanol. SYSTEMATICALLY fits structure to formula.
			3.2	X	-	X	Only 1 stt. "Unable to do"
			3.3	X	3C3, 3B2, 2A1, 3B1, C2	X	Fits structure to formula.
			4.	X	B4	X	Considers it more difficult as there is more than one oxygen. NB This student has not done chemistry at HSC level. (Refer transcript for questionnaire).

No.	Name	Year	Problem No.	Knowledge Test	Strategy	Problem Solved	Remarks
24	Embleton, P.W.	TOP	3.1	✓	B_4, C_3, B_1	X	N-propyl iodide, n-propanol. Doesn't know acetone and feels it would help if he did. N-Propyl iodide → n-propanol.
			3.2		B_1	X	Only 1 statement, "I suppose the Cl would drop out? and gives up.
			3.3	X	$2B_1$, $3C_3$, B_4	X	RANDOM Gives up
			4.	X	B_3, C_3, $2B_4$, A_1	X	You "just put them together" $CH_3CHO + CH_3OH \rightarrow CH_3CH\ OOCH_3 = A$. Fits structure of B to formula using his A as starting point.
24	Pavlovec, L.	CHE III	3.1	X	No tape	X	No answer
			3.2	X	" "	X	" "
			3.3	X	" "	X	" "
			4.	X	" "	X	" "
77	Tassios, Steven	CHE III	3.1	✓	No tape	X	Iodopropane & propanol
			3.2	✓	" "	X	Cyclopentanone.
			3.3	✓	" "	✓	Can't name oxalic acid. B = 2, 3, 4-triolhexanal but can define esterification.
			4.	X	" "	X	
41	Johnson, Robert Kevin.	HSC	3.1	✓	No tape	X	No answer.
			3.2	✓	" "	X	Cyclobutanol.
			3.3	X	" "	X	Structure for oxalic acid OK. No answer for B. Not know esterification.
			4.	X	" "	X	No answer C4.

APPENDIX C

STRATEGY MAP TABLES

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	$C_1 + C_2$ %	
90	B.T. Hart H.O.D. Chem	3.1	✓	✓	$B_1, C_1\ C_2\ D_2\ B_3$	20	0	20	0	40	20	20	0	40	40	Starts c̄ $RI + OH \rightarrow ROH$ ∴ n-Pr-I. but then sees acetone ∴ back to >-I
		3.2	✓	x	$B_1 C_1$	50	0	0	0	50	50	0	0	50	50	replaces Cl by OH. Has trouble cyclizing
		3.3	✓	✓	$C_2\ C_3\ B_4\ C_2\ B_1$	20	0	0	20	40	0	40	20	60	40	logical. oxalic + alcohol → diester
		4	✓	x	–	–	–	–	–	–	–	–	–	–	–	Knows RCHO & RCOH. Cannot proceed,
91	D. Packham Lecturer (Inorganic Chem)	3.1	✓	✓	$C_2 C_3 C_2$	0	0	0	0	0	0	66	33	100	NA	perfect logical. Starts c̄ acetone works backwards.
		3.2	✓	✓	$B_4\ B_4\ B_1\ C_2$	25	0	0	50	75	0	25	0	25	NA	 answer
		3.3	✓	✓	$C_3 C_2\ C_2 C_3$	0	0	0	0	0	0	50	50	100	NA	Gets oxalic & then formula matching.
		4	✓	x	$C_3\ C_2\ B_4\ B_1$	25	0	0	25	50	0	25	25	50	NA	Formula matching → 
92	L. McCarthy Technician	3.1	✓	✓	$B_4\ C_1\ B_4\ C_3\ C_2\ C_2$	0	0	0	33	33	16	33	16	66	50	logical, start c̄ acetone counts atoms ∴ products
		3.2	✓	✓	$B_3\ A_1\ C_2\ B_1$	25	0	25	0	50	0	25	0	50	NA	active bit in the molecule ∴ educational guess
		3.3	✓	✓	$A_2 B_4 C_1 C_3 C_2 C_3 B_4$ $C_2 C_2$	0	0	0	22	22	11	33	11	66	44	logical acid + alc = ester ∴ formula fits
		4	✓	✓	$C_3 B_2 B_2$	0	66	0	0	66	0	0	33	33	NA	first writes CH_3COOMe Then counts atoms & changes. finally correct formula matching.

C2

Table

No.	Name and Year	Problem No.	Know-ledge Test Pass (√) Fail (x)	Problem Solved Yes (√) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	
85	Andrew White CHE 228	3.1	✓	✓	A_1 C_2 C_2	0	0	0	0	0	0	66	0	66	NA	– logical
		3.2	✓	✓	B_4 C_2 C_1 C_2	0	0	0	25	25	25	50	0	75	75	– straight into inductive + deductive statements
		3.3	✓	✓	C_3 D_2 C_2 B_4 C_3	0	0	0	20	20	0	20	40	60	NA	– "
		4	✓	✓	B_3 B_4 C_3 C_2 C_2 B_2	0	16	16	16	48	0	32	16	48	NA	– logical but wrong. Tries various leaving groups Random T&G

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	$C_1 + C_2$ %	Remarks
71	Paul Segar CHE 228	3.1	✓	✓	$C_1 C_1 C_1 C_2 C_2$	0	0	0	0	0	60	40	0	100	100	Many inductive statements Solves it from C⊕ ion angle No formula math.
		3.2	✓	✓	$B_4 B_4$	0	0	0	100	100	0	0	0	0	0	Guessed that –Cl attacks by –OH
		3.3	✓	✓	$C_1 C_2$	0	0	0	0	0	50	50	0	100	100	diacid ∴ diester ∴ oxalic etc
		4	✓	X	–	–	–	–	–	–	–	–	–	–	–	'I give up on this'
53	John Nicolussi CHE 228	3.1	✓	✓	$C_3 B_4 C_2 C_2$	0	0	0	25	25	0	50	25	75	75	systematic T&E
		3.2	✓	✓	$B_2 C_2 C_2$	0	33	0	0	33	0	66	0	66	NA	logical
		3.3	✓	✓	$C_3 C_3 C_1 C_3 B_2$	0	20	0	0	20	20	0	60	80	NA	" sys T&E
		4.	✓	✓	$C_1 B_3 C_3 C_3 C_2 C_1 C_3$	0	0	14	0	14	28	14	42	84	42	" "
16	Rodney Cram CHE 228	3.1	✓	✓	–											No transcript. Scriptbook shows attack by electrons.
		3.2	✓	✓												
		3.3	✓	x												
		3.4	✓	✓												
09	Phil Brewis CHE 228	3.1	✓	✓	$C_3 B_2 C_2 D_1$	0	25	0	0	25	0	25	25	50	50	logical. n-Pr-I initially Changes when sees acetone
		3.2	✓	✓	$A_1 C_3 C_2 C_1 B_3 C_1 D_2$	0	0	14	0	14	28	14	0	42	42	logical
		3.3	✓	✓	$B_4 C_2 A_1 C_2 C_1 C_2 D_1$	0	0	0	14	14	14	42	0	56	56	logical. Conserv. focussing
		4	✓	✓	$A_1 C_2 C_2 C_2 D_1 C_2 C_3$	0	0	0	0	0	0	56	14	70	NA	" "

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 + C_2 %	Remarks
60	Giovanni Della Penna CHE 228	3.1	✓	x	$C_2 C_3 C_2$	0	0	0	0	0	0	66	33	100	NA	answer n-PrI. Info re. acetone not used.
		3.2	✓	✓	C_1 B4 C_2	0	0	0	33	33	33	33	0	66	66	
		3.3	✓	✓	$C_3 C_2 C_1 C_3$ B4 $C_2 C_3 D_1$	0	0	0	12	12	12	24	24	60	36	
		4	✓	✓	$C_1 C_2 C_3 C_3 C_1 D_1$	0	0	0	0	0	32	16	32	80	48	
79	Peter Theodoropoulos	3.1	✓	✓	C_3 B4 $C_2 D_2$	0	0	0	25	25	0	25	25	50	NA	
		3.2	✓	✓	B4 $C_2 D_1$	0	0	0	33	33	0	33	0	33	NA	
		3.3	x	x	C3 B3 B1	33	0	33	0	66	0	0	33	33	NA	Gets oxalic acid, Then random trial-error
		4	✓	✓	$B_2 C_2 C_3$	0	33	0	0	33	0	33	33	66	NA	
01	Andrew Andreou CHE 228	3.1	✓ 11/11	x	B4 B4 C_2	0	0	0	66		0	33	0	33	NA	
		3.2	✓	✓	–											No trascript. Just the correct answer
		3.3	✓	x	B4	0	0	0	100	100	0	0	0	0	NA	Gets oxalic acid but Then forms mono ester
		4	✓	x	C3 B4	0	0	0	50	50	0	0	50	50	NA	Cannot use The knowledge to think of the attack by –OH on –CHO. Just says, " Makes no sense.

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65	Joe Rausa CHE111	3.1	✓	x	$B_1, B_3 B_4, C_3, C_3, D_1$	16	0	16	16	48	0	0	32	32	NA	– n-Pr-I. mere formula matching
		3.2	✓	x	$C_3 B_1$	50	0	0	0	50	0	0	50	50	NA	– only reads problem
		3.3	✓	x	$A_1\ C_1\ C_2\ C_3\ C_3\ B_2$	0	16	0	0	16	16	16	32	64	32	–
		4	✓	x	$A_1\ B_1\ B_1\ B_4\ C_3\ C_3$	32	0	0	16	48	0	0	32	32	NA	– Random T&E
67	Mark Reubenicht CHE111	3.1	✓	x	$B_1\ B_1$	100	0	0	0	100	0	0	0	0	NA	– only 2 statements
		3.2	✓	x	$B_2\ C_3\ A_1\ B_1\ B_1$	40	20	0	0	60	0	0	20	20	NA	– mere formula matching
		3.3	x	x	$B_2\ B_3$	0	50	50	0	100	0	0	0	0	NA	– Doesn't know Ethanol.
		4	x	x	$B_3\ B_4$	0	0	50	50	100	0	0	0	0	NA	– gives up
55	Eric Northeast CHE111	3.1	x	x	$C_2\ C_3 C_3\ B_4\ D_1\ D_1$	0	0	0	16	16	0	16	32	48	NA	– n-Pr-I. mere formula match. Does not use oxdn. data.
		3.2	x	x	–											– skips the problem
		3.3	x	x	$A_1 A_1 B_4 B_4\ D_1 C_3$	0	0	0	32	32	0	0	16	16	NA	– mere formula matching
		4	x	x	$B_4\ B_4\ C_3\ B_3$	0	0	25	50	75	0	0	25	25	NA	– " "
57	Senen Joel Paras CHE 111	3.1	✓	x	$5 \times C_3,\ B_2 D_1 A_1 B_1$	11	11	0	0	22	0	0	33	33	NA	– n-Pr-I. formula matching
		3.2	✓	x	$8 \times C_3,\ 3 \times B_4,\ C_1,\ 2 \times A_1$	0	0	0	21	21	7	0	56	63	NA	– Begins by attempting to see how R^n will occur but finally only formula matching
		3.3	✓	x	$6 \times C_3,\ 2 \times B_3,\ 2 \times B_4$	0	0	20	20	40	0	0	60	60	NA	– only formula match
		4	✓	x	$2A_1,\ 3 \times B_4,\ 8 \times C_3,\ B_1$	7	0	0	21	28	0	0	56	56	NA	– " " "

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					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	
58	Dale Parsell CHE III	3.1	✓	x	–											n-Pr.1. No transcript
		3.2	✓	✓	–											"
		3.3	✓	x	D_1, C_3	0	0	0	0	0	0	0	50	50	NA	Gets oxalic acid structure. Only 2 statements.
		4	✓	x	$A_1, 2\times B_2, C_3, B4$	0	40	0	20	60	0	0	20	20	NA	only 4 statements
63	Tina Pitrone CHE III	3.1	x	x	$5\times A_1, 2\times B_1$	28	0	0	0	28	0	0	0	0	NA	Does not know acetone. Random formula matching.
		3.2	x	x	$5\times B_1, C_2, 4C_3, A_1$	45	0	0	0	45	0	9	36	45	NA	Tries to detn how R^n will occur but random approach
		3.3	x	x	$2C_3, C_2, A_1$	0	0	0	0	0	0	25	50	75	NA	Formula matching
		4	x	x	C_3	0	0	0	0	0	0	0	100	100	0	Does'nt know 'Al'.
64	Mauro Rapuni CHE III	3.1	✓	x	$A_1, 5\times C_3, A_2, B4, 3\times D_1$	0	0	0	9	9	0	0	45	45	NA	n-Pr-I. mere formula match.
		3.2	✓	x	$B4, B_1, C_3$	33	0	0	33	66	0	0	33	33	NA	just reads problem
		3.3	✓	x	B_3	0	0	100	0	100	0	0	0	0	NA	gives up
		4	✓	x	$6\times C_3, B_1, 2\times B_3, 2\times B_4, D_1$	8	0	16	16	40	0	0	48	48	NA	formula matching
75	Alison Swinbank CHE III	3.1	✓	x	Blank tape											–
		3.2	✓	✓	"											Gets oxalic acid only
		3.3	✓	x												–
		4	✓	x	"											'Diethyl ester' as the only answer. guessing & gambling

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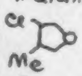
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	
05	Doug Berecic CHE III	3·1	✓	x	2B4, B2, A1, 2C3, 2D1, B3	0	11	11	22	44	0	0	22	22	NA	- n-Pr I: formula matching
		3·2	✓	x	2B3, 6B4, 5A1, 8C3, 2B2, B1	4	8	8	24	44	0	0	32	32	NA	- random formula matching. answer is 
		3·3	✓	x	7C3, A1, B4, B2, 2D1 3B1	19	6		6	31	0	0	45	45	NA	- Gets oxalic acid. then just formula matching
		4	✓	x	3B3, 5B4, 2B1, 7C3, 5D1, A2	8	0	12	20	40	0	0	28	28	NA	- only formula matching.
45	Fiona Laird CHE III	3·1	x	x	4C3	0	0	0	0	0	0	0	100	100	NA	- Does'nt know 'I'
		3·2	x	x	C3	0	0	0	0	0	0	0	100	100	NA	- just reads Q.
		3·3	x	x	2C3	0	0	0	0	0	0	0	100	100	NA	- Does'nt know EtOH
		4	x	x	B4 B3 C3	0	0	33	33	66	0	0	33	33	NA	- Does'nt know EtOH, MeOH
* 33	Paul Haviaridd CHE III	3·1	x	x	3B4, C3, B1, 2D1	14	0	0	42	56	0	0	14	14	NA	- n-Pr-I & propanol just formula matching
		3·2	x	x	-											-
		3·3	x	x	2B4, D1	0	0	0	66	66	0	0	0	0	NA	- wild random guess Does'nt ever check if it fits formula
		4	x	x	2B4, B1, 2D1	20	0	0	40	60	0	0	0	0	NA	- (same " strategy " for all ?)
36	Foo Nin Ho CHE III	3·1	x	x	C3	0	0	0	0	0	0	0	100	100	NA	-
		3·2	x	x	} Not attempted											-
		3·3	x	x												-
		4	x	x												-

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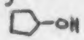
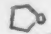
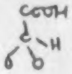
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	
62	John Phillips CHE III	3·1	✓	x	B_4, B_3, $2D_1$, C_1, B_1	20	0	20	20	60	20	0	0	20	NA	n-Pr-I & propanol
		3·2	✓	x	4C_3, 2B_4, 4B_1, 2B_3, C_2, B_2	28	7	14	14	63	0	7	28	35	NA	random guess answer  -OH
		3·3	x	A✓ B x	2B_4, 9C_3, 2D_1, B_3	0	0	7	14	21	0	0	63	63	NA	random guess
		4	x	x	11 C_3, 3 B_3, 4B_1, B_4	20	0	15	5	40	0	0	55	55	NA	Does'nt know EtOH
* 89	Kevin Woodward CHE III (P/T)	3·1	✓	✓	B_1, B_2 C_2, C_3, B_4	20	20	0	20	60	0	20	20	40	NA	Starts systematically but then lost. Reverts to focus gambling using acetone as a (+ve) instance & Works backwards.
		3·2	✓	✓	C_2 B_1, B_1	66	0	0	0	66	0	33	0	33	NA	focus gambling again Uses  as focus & then tries structure fit
		3·3	✓	x	B_4 C_3 C_1	0	0	0	33	33	33	0	33	66	NA	**Set**. Cannot get oxalic acid structure Writes  COOH H knows acid + alcohol → ester but cannot use it
		4	x	x	B_1, C_2, C_3, B_1, C_3	40	0	0	0	40	0	20	40	60	NA	Does not know Ethanal. All 4 problems with similar strategies

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					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	$C_1 + C_2$ %	
61	Maritta Pfauder CHE III	3.1	✓ (?)	X	A_1 C_2 C_2	0	0	0	0	0	0	66	0	66	NA	Wrong deduction 1°alcohol $\xrightarrow{O}$ ketone
		3.2	✓	✓	A_1 B_2 B_4 C_2	0	25	0	25	50	0	25	0	25	NA	logical 4 statements
		3.3	✓	x	B_4, C_1, C_3, B_2, C_2, C_3	0	16	0	16	32	16	16	16	48	32	Gets oxalic acid. knows acid+alc=ester but gets ester structure wrong
		4	✓	x	A_1 B_1 C_3 B_1	50	0	0	0	50	0	0	25	25	NA	random trials to fit structure
74	Phillip Stuckley	3.1	x	x	–											No transcript
		3.2	✓	✓	C_1 C_2	0	0	0	0	0	50	50	0	100	100	one statement only,
		3.3	x	x	–											Does not know EtOH
		4	x	x	C_1 C_2 C_3 B_1 B_1	40	0	0	0	40	20	20	20	60	40	Random attack
70	G. Scott CHE III	3.1	x	x	–											Not recorded
		3.2	✓	x	–											"
		3.3	✓	x	B_4 C_3 C_2 B_4											Gets oxalic by a deductive approach
		4	✓	x	–											Not recorded.
48	Trinh Luu CHE III	3.1	✓ 11/11	X	-											Not attempted
		3.2	✓	x	B_4 C_3	0	0	0	50	50	0		50	50	NA	only 3 statements answer ⬠=O
		3.3	✓	✓	A_1 B_4 C_2 C_3 D_1	0	0	0	20	20	0	20	20	40	NA	Classical logical approach. 7 statements No mumbling like before.
		4	✓	X	A_1 C_3 C_1 C_3	0	0	0	0	0	25	0	50	75	NA	Wrong deduction alcohol + aldehyde → ester

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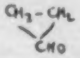
21	Brett Dixon CHE III	3.1	✓	✓	3A1, B4, 2D1, 3B2, 2C2, B3, A1, C3	0	21	7	7	35	0	14	7	21	NA	Sys-trial-error
		3.2	✓	x	A1, C3	0	0	0	0	0	0	0	33	33	NA	2 statements only
		3.3	x	x	4C3, B3, 3C2, 2D1, 2B2, 2B4, A1, C1, B1	6	12	6	12	36	6	18	24	48	24	Does not know esterification
		4	x	x	C2 C3	0	0	0	0	0	0	50	50	100	NA	mere manipulation
44	Bernard Kuran CHE III	3.1	✓ 11/11	x	C1 C2 C3 B2 D1	0	20	0	0	20	20	20	20	60	40	Cannot recognize that ketones come from sec-alcohol otherwise logical
		3.2	✓	x	B1 B4 C2	33	0	0	33	66	0	33	0	33	NA	 answer
		3.3	✓	x	B4 C2 B1	33	0	0	33	66	0	33	0	33	NA	Gets 2x COOH but cannot work out how to put them together Set
		4	✓	x	C3 B1	50	0	0	0	50	0	0	50	50	NA	Ethanol Wrong formula. Then random T&E
54	M.P. Lo Nigro CHE III	3.1	x	x	B4, C3, C2, C3, B1, B4	16	0	0	32	48	0	16	32	48	NA	Doesn't know acetone
		3.2	✓	x	C3 B1 B4 B1 C3	40	0	0	20	60	0	0	40	40	NA	Random T&E formula fitting
		3.3	✓	x	–											No transcript. Gets oxalic acid then formula matching
		4	✓	x	–											Formula matching.

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Table

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					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	$C_1 + C_2$ %	
84	Peter Vass CHE III	3.1	✓	x	-											Not attempted. "I don't understand it"
		3.2	✓	x	B4											just reads 3 times
		3.3	✓	x	C_2 B_1 C_3 C_3 B_1	20	0	0	20	40	0	20	40	60	NA	Gets oxalic acid Then simply formula matching Random T&E.
		4	✓	x	B4	0	0	0	100	100	0	0	0	0	NA	Reads 3 timer NA
18	Michael De Felice CHE III	3.1	✓	A x B ✓	$3A_1$, $2D_1$, $2B_3$, B_2, $5C_3$, B4.	0	7	14	7	28	0	0	21	21	NA	A = propyl iodide B = 2-propanol
		3.2	✓	x	$2B_2$, 2B4, $3C_3$, D_1, $2B_1$, $3A_1$	16	16	0	16	48	0	0	24	24	NA	
		3.3	✓	x	$8C_3$, $10A_1$, 3B4, 3B3, $2B_2$, $2A_2$, $2C_2$, C_1, D1.	0	6	9	9	24	3	6	24	33	9	Gets oxalic acid but cannot accept its existence. "Set" Recognizes ester formation. The 2nd COOH upsets him.
		4	✓	x	$16C_3$, $12A_1$, 3B4, $10B_1$, $3B_2$, A_2, C_2, D_1, B3	10	6	2	6	24	0	2	32	34	NA	Focus gambling gone wrong. 'consider A is an acid" & B an ester Random T&E

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						B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	% $C_1 + C_2$	
86	Adam Wittmer CHE III	3.1	✓	x	$B_1 C_3$	50	0	0	0	50	0	0	50	50	NA	
		3.2	✓	✓	B_1, B_4	50	0	0	50	100	0	0	0	0	NA	Incomplete protocol. first random TE Then 'I've got it'.
		3.3	✓	x	$B_2 C_3$	0	50	0	0	50	0	0	50	50	NA	Cannot get oxalic acid ∴, Resorts to Random T&E
		4	✓	x	B4	0	0	0	100	100	0	0	0	0	NA	Formula matching
76	Lynn Tan CHE III	3.1	x	x	x											mostly mumble & then, "I Can't do it"
		3.2	x	x												
		3.3	x	x												
		4	x	x												
81	Garry Thurley CHE III	3.1	✓	x	B4 C_1 B4 B1	25	0	0	50	75	25	0	0	25	NA	n-propanol & n-Pr-I. Acetone Info. not used
		3.2	✓	x	C_2B4	0	0	0	50	50	0	50	0	50	NA	Random T&E
		3.3	✓	x	C_2, C_3	0	0	0	0	0	0	50	50	100	NA	$\square^{MC}$ the answer Gets oxalic acid but then just formula matching fails.
		4	✓	x	B_1	100	0	0	0	100	0	0	0	0	0	Random T&E Random formula matching. fails
87	Kim Wong CHE III	3.1	x	x	–											
		3.2	x	x	–											
		3.3	x	x	–											
		4	✓	x	B4, B_2, B4	0	33	0	66	100	0	0	0	0	NA	Mere formula matching.

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					Strategy Map	B1 %	B2 %	B3 %	B4 %	To-tal B %	C_1 %	C_2 %	C_3 %	To-tal C %	C_1 % + C_2	
29	Patrick Griffin CHE III	3.1	✓	✗	3×B_4, 2×C_2, 2×C_3, B_3 B_1, A_2	10	0	10	30	50	0	20	20	40	NA	Does not know acetone
		3.2	✓	✗	A_1 2×B_4, A_2, 2×C_3	0	0	0	32	32	0	0	48	48	NA	
		3.3	✓	A ✓ B ✗	C_1, 4×B_4, 19 C_3, 6A_2 6B_1, 2D_1, 2B_2, 2A_1, B3	14	4	2	10	30	2	0	44	46	NA	Tries formula fit after every step
		4	✓	✗	2C_2, 3B_3, 5B_4, 2B_1, 10C_3, 2A_1, 2B_2	9	9	13	23	54	0	9	46	55	NA	Recognises R^n of RCHO + R'OH. Tries to fit structure to the formula using MeOH to be added
23	Paul Dossor CHE III	3.1	✗	B ✗, A ✓	No transcript	-	-	-	-	-	-	-	-	-	-	B = Me Me Sod propanate ONa
		3.2	✓	✗	B_3 B_4 A_1 D_1 C_3	0	0	20	20	40	0	0	20	20	NA	
		3.3	✗	✗	C_3 B_2 B_4	0	33	0	33	66	0	0	33	33	NA	Only 2 statements
		4	✓	✗	5C_3 C_2 3B_2 3A_2 3A_1 3B_4 D_1 B_3	0	15	5	15	35	0	5	15	20	NA	Tries to fit structure to formula
22	Mike Dore CHE III	3.1	✓	✓	C_1, 3C_2, 2B_4, 5C_3, A_2, 3B_2, 2D_1, 4A_1, D_2	0	13	0	9	22	4	0	22	26	NA	Fits acetone structure to formula Then checks oxdn Sys trial-error
		3.2	✗	✗	2A_1 B_4 C_3	0	0	0	25	25	0	0	25	25	NA	
		3.3	✗	A ✓ B ✗	2A_1, 2B_4, 5C_3, 2A_2, B_1, D_1, B3	7	0	7	14	28	0	0	35	35	NA	Gets oxalic acid by formula fit. Fails this method in formula fitting 'B'
		4	✗	✗	3C_3, B_4, C_1, A_1, 3B_3, 2B_1, B_2, A_2	16	8	24	8	56	8	0	24	32	NA	Sys trial-error Tries to react RCHO & ROH. Sys trial-error

Table

No.	Name and Year	Problem No.	Knowledge Test Pass(✓) Fail(x)	Problem Solved Yes(✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	
27	Paul Freeman CHE III	3.1	✓	X	B4 C_2	0	0	0	50	50	0	50	0	50	NA	Wrong deduction since acetone ∴ 3° alcohol
		3.2	✓	X	B4 B_2	0	50	0	50	100	0	0	0	0	NA	Was on right track "off Cl & H." But al removes OH.
		3.3	✓	X	B4 B4	0	0	0	100	100	0	0	0	0	NA	Right track. Says A is dicarbo and B is ester
		4	✓	X	B4	0	0	0	100	100	0	0	0	0	NA	RCHO + RCH → acid wrong deduction.
43	Ivan Kulikov CHE III	3.1	X	X	B_2 $C_2C_2C_3$	0	25	0	0	25	0	50	25	75	NA	Does not know ketones
		3.2	✓	X	A_1 C_3 C_2 B_3	0	0	25	0	25	0	25	25	50	NA	☐ on answer Has los methyl group.
		3.3	X	X	B_1 C_2C_3	33	0	0	0	33	0	33	33	66	NA	Arranges random structures to fit The formula.
		4	✓	X	C_3 C_3 B4 B_1	25	0	0	25	50	0	0	50	50	NA	random T&E
50	Peter Meggs CHE III	3.1 3.2 3.3 4	X	X	–											No transcript
49	Angelo Morken CHE III	3.1	✓	X	C_3C_2	0	0	0	0	0	0	50	50	100	NA	n-Pr-I answer. Tries formula fit
		3.2	✓	✓	C_3	0	0	0	0	0	0	0	100	100	NA	Too short transcript
		3.3	✓	X	–											Gets oxalic acid but does not know esterification
		4	✓	X	–											no recording.

C15

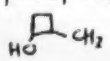
Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 + C_2 %	
02	Ken Arnolda CHE 111	3.1	✓	x	B1	100	0	0	0	100	0	0	0	0	NA	Random T&E Only 4 statements
		3.2	✓	✓	B4	0	0	0	100	100	0	0	0	0	NA	Guesses structure
		3.3	✓	x	B1	100	0	0	0	100	0	0	0	0	NA	Guesswork. Random T&E
		4	x	x	–											Not attempted
07	George Bingley CHE III	3.1	x	x	–											Not attempted
		3.2	x	x	–											" "
		3.3	x	x	B_1	100	0	0	0	100	0	0	0	0	NA	only 4 statements
		4	x	x	B_1	100	0	0	0	100	0	0	0	0	NA	only 6 statements
10	R. Bucher CHE III	3.1	✓	x	A_1, B4, B4	0	0	0	66	66	0	0	0	0	NA	R-I → R-OH deduced
		3.2	✓	x	–											Just reads problem over & over again
		3.3	✓	✓	C_1 C_2 B_1 B_1 B4 D_2	32	0	0	16	48	16	16	0	32	32	
		4	✓	x	A_1 B_1	50	0	0	0	50	0	0	0	0	NA	Stuck.
17	Lawrence Dean CHE III	3.1	✓	x	A_2 B_2 B4 C_2	0	25	0	25	50	0	25	0	25	NA	–
		3.2	✓	x	A_2 B_1 B4 C_2	25	0	0	25	50	0	25	0	25	NA	Random T&E
		3.3	✓	✓	B_2 C_2 C_3 C_3 B4	0	20	0	20	40	0	20	40	60	NA	
		4	✓	x	B4, B4, 3C_3, C_2 B_1 B_2	12	12	0	24	48	0	12	36	48	NA	Random T&E (formula matching)
15	Mark Coleman CHE 111	3.1	✓	x	B4 B_1 A_1 C_2	25	0	0	25	50	0	25	0	25	NA	Random T&E
		3.2	✓	x	A_1 B4 C_2	0	0	0	33	33	0	33	0	33	NA	Realises 'C1' must go
		3.3	x	x	–											Does'nt know what 'ol' is.
		4	x	x	–											Just reads problem.

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	$C_1 + C_2$ %	
13	Russell Christian CHE III	3.1	x	x	B_4	0	0	0	100	100	0	0	0	0	NA	only 3 statements
		3.2	x	x	B_4 A_1 C_1 C_3	0	0	0	25	25	25	0	25	50	NA	Too many false assumptions Random T&E
		3.3	✓	x	B_4 B_1	50	0	0	50	100	0	0	0	0	NA	Wrong inferences
		4	x	x	B_4 B_1	50	0	0	50	100	0	0	0	0	NA	" "
31	Paul Haines CHE III	3.1	✓	x	B_1, B_4, C_2	33	0	0	33	66	0	33	0	33	NA	mere formula matching No thought given to acetone
		3.2	x	✓	B_1	100	0	0	0	100	0	0	0	0	NA	just by fluke got The Correct structure
		3.3	✓	x	A_2 B_1 B_1 B_1 C_3 C_3	48	0	0	0	48	0	0	32	32	NA	Gets oxalic acid by formula matching
		4	x	x	B_1 C_3	50	0	0	0	50	0	0	50	50	NA	mere formula matching A strong focus gambler
34	Adrian Hegedus CHE III	3.1	✓	x	A_1 B_2 B_4 C_2 C_3	0	20	0	20	40	0	20	20	40	NA	Cannot Work out $\rangle{=}O \rightarrow \rangle^{H}_{OH}$ relation
		3.2	✓	x	—											Not attempted
		3.3	✓	x	A_1 B_1	50	0	0	0	50	0	0	0	0	NA	" "
		4	✓	x	B_1	100	0	0	0	100	0	0	0	0	NA	" "
35	Duong Ho CHE III	3.1	✓	x	—											Not attempted
		3.2	✓	x	—											"
		3.3	✓	x	–											"
		4	✓	x	–											"

Table

No.	Name and Year	Problem No.	Knowledge Test Pass(✓) Fail(x)	Problem Solved Yes(✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 + C_2 %	
32	Chris Hall CHE III	3.1	✓	X	B1 C_2 C_3	33	0	0	0	33	0	33	33	66	NA	Gambling just writes 'a' structural formula for the M.F. given
		3.2	✓	x	C_1 C_2 B4	0	0	0	33	33	33	33	0	66	NA	Correct deduction: C_1 has got to go
		3.3	✓	x	B_1 C_1 C_1 C_2 B4	20	0	0	20	40	40	20	0	60	60	Gets oxalic acid Then just adds groups to match formula. No logical thought.
		4	✓	x	A_1 B_1 F. C_3 B4	40	0	0	20	40	0	0	20	20	NA	random T&E to fit structures to M.F.
30	Mark Graesser CHE 111	3.1	✓	X	–											just reads
		3.2	✓	–	–											No recording
		3.3	✓	x	–											" "
		4	X	x	B_1 B4	50	0	0	50	100	0	0	0	0	NA	Random T&E
38	Ron Hubeck CHE III	3.1	✓	✓	A_1, A_1 C_2, C_3 C_3, B_2, D_1	0	14	0	0	14	0	14	28	56	NA	Sys. trial-error Logical
		3.2	✓	x	A_1 A_2 C_2 B4 D_1	0	0	0	20	20	0	20	0	20	NA	correct formula matches but cannot think of 'o' as part of ring ∴ Writes  **Set**
		3.3	✓	x	B4, B4, B_1, C_2, C_3, C_3, D_2	0	0	0	28	28	0	14	28	42	NA	
		4	X	x	C_2 C_3	0	0	0	0	0	0	50	50	100	NA	Doesn't know Ethanol

Table

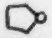
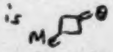
No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	$C_1 + C_2$ %	Remarks
40	Stephen Jirik CHE III	3.1	x	x	C_3 C_3 B_4	0	0	0	33	33	0	0	66	66	NA	Doesn't know acetone
		3.2	✓	x	B_4 C_3	0	0	0	50	50	0	0	50	50	NA	Writes  but no methyl group
		3.3	✓	x	B_4 C_2 C_1 C_3 D_2	0	0	0	20	20	20	20	20	60	40	Comes very close Gets oxalic acid & makes COCl COOH
		4	✓	x	–											Gives up
12	Thierry Chan CHE III	3.1 ↓ 4	x x x x	x x x x	–											No recording
66	P. Recinella CHE III	3.1	x	x	–											No recording Writes n-Pr I
		3.2	x	x	–											No recording
		3.3	✓	x	B_4	0	0	0	100	100	0	0	0	0	NA	
		4	✓	x	–											No recording. mere formula matching
56	Victor Nyunt CHE III	3.1	✓	x	–											No. Rec n-Pr I
		3.2	✓	x	–											No Rec
		3.3	x	x	–											–
		4	x	x												mere formula matching
52	Terry Mouncy CHE III	3.1	✓	x	–											No rec n-Pr-I
		3.2	✓	x	–											" " Cl has been removed. Structure written is 
		3.3	✓	x	–											Gets oxalic acid & mono ester
		4	✓	x												Not attempted

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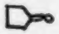
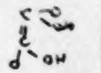
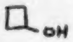
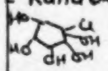
Table

No.	Name and Year	Problem No.	Knowledge Test Pass(✓) Fail(x)	Problem Solved Yes(✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 + C_2 %	
59	L. Pavlovic CHE III	3.1	x	x	No tape											–
		3.2	x	x												
		3.3	x	x												
		4	x	x												
77	Steven Tassias CHE III	3.1	✓	x	No tape											n-Pr.I & Propanol
		3.2	✓	x												 Random TRE
		3.3	✓	A ✓ B x												oxalic acid✓ then formula matching
		4	x	x												–
19	NIC De Marchi CHE III	3.1	x	x	4 B_4, 5 B_2, C_2, 6 C_3, 2 A_1 A_2 D_1	0	25	0	20	45	0	5	30	35	NA	n-Pr-OH formula matching
		3.2	x	x	–											Gives up
		3.3	x	x	3 C_3, 3 B_2, 2 A_1, 3 B_1, C_2	36	36	0	0	72	0	12	36	48	NA	formula matching to structure
		4	x	x	B_4	0	0	0	100	100	0	0	0	0	NA	
06	Bryant Bernstein CHE III	3.1	x	x	5 C_3	0	0	0	0	0	0	0	100	100	NA	Does'nt know acetone
		3.2	✓	✓	2 B_1, 3 A_1, 3 C_3, B_4, C_2	20	0	0	10	30	0	10	30	40	NA	Realises [illegible] takes off H^+, Cl^- comes off etc. systematic approach
		3.3	x	x	2 C_1, C_3, C_2, B_3, 4 B_2, A_2 B_1	9	36	9	0	54	18	9	9	36	27	Recognizes 2 acid groups but draws them as 
		4	x	x	2 B_2, 2 B_4, B_3, 2 B_1, 3 C_1 11 C_3	10	10	5	10	35	15	0	55	60	NA	fits structures to formula.

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	$C_1 + C_2$ %	
78	Linda Thatcher CHE III	3.1	✓	x	$C_3 B_4$	0	0	0	50	50	0	0	50	50	NA	n-Pr-I & propanol Ignores acetone mere formula match
		3.2	✓	✓	$C_3 B_4 B_4 C_2 C_2 C_2$	0	0	0	32	32	0	48	16	64	NA	Focus Gambling. Recognises loss of HCl & then uses it to make 2-3 guesses to arrive at the correct structure
		3.3	✓	x	$B_1 C_3 B_4 C_3 C_3 C_3$	16	0	0	16	32	0	0	64	64	NA	Gets oxalic acid but then just formula matching
		4	x	x	$B_1 C_3 C_3$	33	0	0	0	33	0	0	33	33	NA	random formula matching

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	
41	Robert K. Johnson HSC	3.1	✓	x	No tape											-
		3.2	✓	x												
		3.3	x	x												oxalic acid✓
		4	x	x												-
08	Lydia Bosa H.S.C.	3.1	✓	x	2 B_2, 4 C_3, D_1	0	28	0	0	28	0	0	56	56	NA	n-Pr-OH & n-Pr-I Fits structure to formula
		3.2	✓	x	C_3	0	0	0	0	0	0	0	100	100	NA	
		3.3	x	x	2 B_2, 15 C_3, 7 B_1, B3, D1	28	8	4	0	40	0	0	60	60	0	Random T&E to fit structures to formulae
		4	x	x	10 C_3, 2 B1, 2 C_1	14	0	0	0	14	14	0	70	84	NA	Does'nt know ketone
46	Jane Leitch HSC	3.1	x	x	–											Does'nt know acetone
		3.2	x	x	B1, B4, 5 C_3	14	0	0	14	28	0	0	70	70	NA	Random wild guess
		3.3	x	x	7 C_3, B_3, B_1	11	0	11	0	22	0	0	77	77	NA	 Does'nt know EtOH
		4	x	x	–											gives up
37	Jacob Holvast H.S.C.	3.1	✓	x	B_3, B_4, 2 B_1, B_2, C_3, D_1	28	14	14	14	70	0	0	14	14	NA	n-Pr-I & propanol. just formula fitting
		3.2	✓	x	3 B4, 3 C_1, 7 C_3, 3 A_1, 3 B1	15	0	0	15	30	15	0	35	50	NA	'Cl' will be pushed out. Then just write a structure to fit formula.
		3.3	✓	✓	B_3, 2 C_1, 5 C_3, 3 B_1, 2 B_4	24	0	8	16	48	16	0	24	40	NA	oxalic acid✓ Recognizes B as ester but no idea of its structure
		4	✓	x	B_1, 2 D_1	33	0	0	0	33	0	0	0	0	NA	A - aldehyde B - ester

Table

No.	Name and Year	Problem No.	Knowledge Test Pass(✓) Fail(x)	Problem Solved Yes(✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	
83	Gary Van Dupin HSC	3.1	✓	x	No recording											– Iodopropyl & t-Me- ether
		3.2	✓	x												–
		3.3	x	x												– oxalic acid ✓
		4	x	x												– matches structures to formula
25	F.J. Fernandez HSC	3.1	x	x	No recording											–
		3.2	x	x												
		3.3	x	x												
		4	x	x												
39	Anthony Jayamaha HSC	3.1	✓	✓	$2D_1, B_3, 5B_4, 7C_3, \rightarrow -2A_2$	0	0	6	30	36	0	0	42	42	NA	– Fits structure to formula
		3.2	✓	x	$21C_3, 4B_1, B_3, 2B_4, B_2$	14	3	3	7	27	0	0	72	72	NA	– " "
		3.3	✓	✓	$3B_3, 2C_2, B_1, D_1, B_4$	12	0	36	12	60	0	24	0	2	NA	– oxalic acid ester ✓
		4	x	x	$2C_2, 9C_3, 2B_3, 5C_1, 2B_1, B_4, A_1, B_2$	9	4	9	4	26	14	9	43	66	23	– many attempts at structure fits

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 + C_2 %	
69	Mehmet Saracoglu T.O.P.	3.1	x	x	$2A_1, 4B4, 2B_2, 2D_1, B_1$	9	18	0	36	63	0	0	0	0	NA	A= propiodone(l) B = propanol
		3.2	x	x	$2B4, 2A_1, D_1$	0	0	0	40	40	0	0	0	0	NA	Ans: Cyclo-2-methyl propanol (l).
		3.3	x	x	$2C_3, A_1 3B_1$	48	0	0	0	48	0	0	48	48	NA	Wild guesses
		4	x	x	$B_2, B4, 2A_1, 2B_1$	32	16	0	16	64	0	0	0	0	NA	x x
26	Maurice Freeman T.O.P.	3.1	✓	x	No recording											Propan-2-ol drawn
		3.2	x	x												no answer
		3.3	x	x												x x
		4	x	x	B_3, C_1, B_1	33	0	33	0	66	33	0	0	33	NA	No background knowledge
03	Ho kimba T.O.P.	3.1	✓	x	$4C_3, B1$	20	0	0	0	20	0	0	80	80	NA	lost
		3.2	x	x	$C_3, 2A_1, 2B1$	40	0	0	0	40	0	0	20	20	NA	Fitting structure to formula.
		3.3	x	x	$4C_3, 5B_1, 2A_1$	55	0	0	0	55	0	0	44	44	NA	" " "
		4	x	x	$8C_3$	0	0	0	0	0	0	0	100	100	NA	Wild guesses

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	
24	P.W. Embleton T.O.P.	3.1	x	x	B_4 C_3 B_1	33	0	0	33	66	0	0	33	33	NA	n-Pr-I & propanol Does'nt know acetone & feels it would help if he did.
		3.2	✓	x	B1	100	0	0	0	100	0	0	0	0	NA	"I suppose the Cl would drop out" Gives up.
		3.3	x	x	2 B_1, 3 C_3, B_4	32	0	0	16	48	0	0	48	48	NA	Random T&E.
		4	x	x	B_3, C_3, 2 B_4, A_1	0	0	20	40	60	0	0	20	20	NA	" " formula fitting
11	Renato Carinci T.O.P.	3.1	✓	x	3 B_4, 2 B_3, C_2, 9 C_3, B_2 A_1	0	6	12	18	36	0	6	0	6	NA	B: n-propanol Recognises $OH^{\ominus}$ attack Fits structure to MF.
		3.2	x	x	–											lack of background knowledge
		3.3	✓	x	8 C_3, B_2, C_2, B_1, B_4, B_3, D_1, 5 C_3	5	5	5	5	20	0	5	65	70	NA	fits structure to formula.
		4	x	x	2 A_1											
72	Philip Starr T.O.P.	3.1	✓	✓	A_1, C_3, 2 B_4, 2 D_1	0	0	0	32	32	0	0	32	32	NA	acetone ⇒ 2° alcohol ∴ solution A = iodopropane : no structu
		3.2	✓	x	3 B_4, A_1, C_3, D_1	0	0	0	48	48	0	0	16	16	NA	
		3.3	✓	x	3 C_3, 4 B_1, A_2 B_4	44	0	0	11	55	0	0	33	33	NA	**Set**. Can't accept existence of oxalic acid. Considers an ester but unable to get structure
		4	x	x	2 B_4, 4 C_3, 2 B_3, 5 B_1, 2 D_1	35	0	14	14	63	0	0	28	28	NA	Considers various classes of compds to try to fit the structures to MF.

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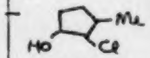
Table

No.	Name and Year	Problem No.	Knowledge Test Pass(✓) Fail(x)	Problem Solved Yes(✓) No (x)	Strategy Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 % + C_2	Remarks
88	Peter Wood T.O.P	3.1	✓	✓	2B4, 4A_1, 4C_3, B_2, 2D_1	0	8	0	16	24	0	0	32	32	NA	ketone ⇒ 2° alcohol ⇒ 2° alkyl halide Conserv. focussing.
		3.2	✓	✓	B_2, 2B1, 2B4, 2C_3	28	14	0	28	56	0	0	28	28	NA	→ Cl ⇒ HCl loss ⇒ structure
		3.3	✓	✓	4B4, 3C_3, 2D_1, A_1	0	0	0	40	40	0	0	30	30	NA	Recognizes ester formation immediately
		4	×	×	12C_3, 5B4, 2B_2, D_1, 2A_1	0	9	0	22	31	0	0	54	54	NA	Recognizes that >=O reacts with –OH. Unable to get product structure. Strategy same for all 4 questions. Also note that No C_1 & C_2 but still gets answers right.
04	Con Baksheev T.O.P.	3.1	✓	×	3B4, 3C_3, A_1	0	0	0	42	42	0	0	42	42	NA	Recognizes 2° alcohol but can't use the info.
		3.2	✓	×	–											–  answer no transcript.
		3.3	✓	×	10C_3, B4, 3B1, 2A_2	18	0	0	6	24	0	0	60	60	NA	fits structure to formula
		4	×	×	4B4, 2B3, C_3	0	0	14	28	42	0	0	7	7	NA	aldehyde + alcohol ↓ acid
20	Rodney Ditchfield Top	3.1	✓	✓	Blank tape											–
		3.2	✓	×												
		3.3	✓	×												
		4	×	×												

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
						B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	C_1 + C_2 %	
42	CON Karayiannakis T.O.P.	3.1	x	x	5 C_3, 3 B_3, 2 B_1, B_4, B_2 3 A_1	14	7	21	7	49	0	0	35	35	NA	sys plan of attack
		3.2	x	x	-											No answer on tape
		3.3	x	x	2 B_4, B_3, 3 C_3, 2 A_1, C_2, 2 B_1 2 A_2	16	0	8	16	40	0	0	24	24	NA	random formule fitting ″
		4	x	x	7 C_3, 3 B_3, B_1, 3 A_1, 5 B_4, A_2, D_1	5	0	15	25	45	0	0	35	35	NA	″ ″
47	Peter Luck T.O.P.	3.1	x	x	No trascript											A = iodopropane
		3.2	x	x												
		3.3	x	x												
		4	x	x												
51	Zoran Memed T.O.P.	3.1	x	x	No transcript											-
		3.2	x	x												
		3.3	x	x												
		4	x	x												
73	Stephen Staunton T.O.P.	3.1	✓	x	No transcript											A = n-PrI B = n-PrOH
		3.2	✓	x	B_1 3 x C_3	25	0	0	0	25	0	0	75	75	NA	Random formule fitting
		3.3	✓	x	B_3, 13 C_3, 4 B_4, C_1, 3 A_1, 3 B_1, A_2	12	0	4	16	32	4	0	52	56	NA	Gets oxalic acid. then formule fitting.
		4	x	x	2 B_3, 8 C_3, 5 B_1, B_2, B_4 2 A_2	25	5	10	5	45	0	0	40	40	NA	randon formule fitting

Table

No.	Name and Year	Problem No.	Knowledge Test Pass (✓) Fail (x)	Problem Solved Yes (✓) No (x)	Strategy											Remarks
					Strategy Map	B1 %	B2 %	B3 %	B4 %	Total B %	C_1 %	C_2 %	C_3 %	Total C %	$C_1 + C_2$ %	
14	Danny Cochrane T.O.P.	3.1	✓	x	$2D_1$	0	0	0	0	0	0	0	0	0	NA	– wrong guess
		3.2	✓	✓	B4 B_1 A_1	33	0	0	33	66	0	0	0	0	NA	– –
		3.3	x	x	$2B_3, 2B_1, A_1, 2A_2, C_3$	24	0	24	[illegible]	48	0	0	12	12	NA	– tries to fit structures to formula.
		4	✓	x	2 B4, $2C_3, 2B_1, B_3, D_1, A_1$	22	0	11	22	55	0	0	22	22	NA	– –
80	Thomas Neale T.O.P.	3.1	✓	✓	B4, $C_2, 2D_1, 4C_3, B_3$	0	0	11	11	22	0	11	44	55	NA	–
		3.2	✓	x	B4, 3 B1, $2C_3$	48	0	0	16	64	0	0	32	32	NA	– random T&E
		3.3	x	x	B_3, 5 C_3, 3 B1	33	0	11	0	44	0	0	55	55	NA	– " formula fitting
		4	x	x	2 B4, $B_1, 3C_3, 2A_2, B_3$	11	0	11	22	44	0	0	33	33	NA	– " "
82	George Tlas T.O.P.	3.1	✓	x	5 A1, 4B4, D_1, C_3, B_3	0	0	8	32	40	0	0	8	8	NA	– n-Pr-I & propanol
		3.2	✓	x	$5A_1$, 4B4, B_1, C_3, D_1	8	0	0	32	40	0	0	8	8	NA	– Random T&E gabbling
		3.3	x	x	B4	0	0	0	100	100	0	0	0	0	NA	– –
		4	x	x	B_3, 2 B4, C_3	0	0	25	50	75	0	0	25	25	NA	– –
68	Ali Saracoglu T.O.P.	3.1	✓	x	A; B4, 4 C3, D1	0	0	0	14	14	0	0	56	56	NA	– n-Pr-I, B = [illegible]
		3.2	x	x	–											– ans - n-butyl chloride
		3.3	x	x	5C3, 2A1, D1, C_2, B4, B_1 A_2	8	0	0	8	16	0	0	40	40	NA	– wild guesses. C_6H_{10} - benzene
		4	x	x	–											– gives up.
28	Yat man Fung TOP.	3.1	✓	x	– No transcript											–
		3.2	x	x												
		3.3	x	x												
		4	x	x												